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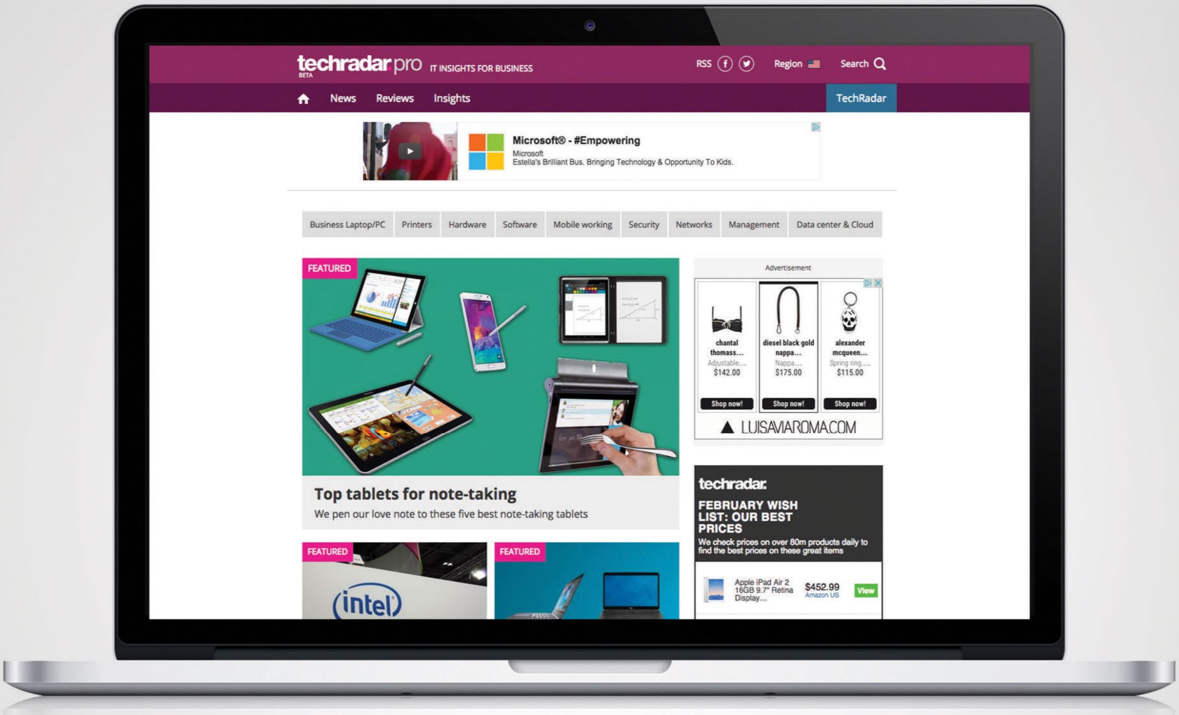
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Guy
Cocker

# TRIPLE THREAT TIME

**NOW THAT I'VE BEEN** at the helm of this fine publication for five months, I thought it was time for us to try something we've never done before: a three-build special. Sure, we've done two-build head-to-heads before, like our popular Intel vs AMD challenges, but they're usually taken on by two writers who split the workload between them. In this issue, it's three machines covering the 1080p/1440p/4K sweet spots, by just one writer.

Like most editors, I'm cheekily taking credit for someone else's brilliant idea here—it was Christian who dreamt up this insane challenge a couple of months ago and, like some mad genius, he's been masterminding it ever since. Christian is a master builder with many years of experience crafting PCs for *Maximum PC*, but I cannot overstate the challenge he set himself: picking the components, getting them in, building the systems, testing them, and then wrapping that all up into one easy-to-follow feature was a monumental task.

The result of Christian's ambition, though, is the answer to a simple question for PC builders: how do I get the best bang for my buck? It doesn't matter if you have $1,200 or $3,600, you still want value for money and our guide covers how to achieve that across three different builds. So, whether you're gaming on a sub-$200, 1080p display or cranking the ray tracing up to max on a 4K monitor, we'll tell you the parts to buy and how to build the system of your dreams. It begins on page 16.

One of the things I love about PC gaming is how inclusive it is. You can get a great gaming system for not much more than $1,000, or you can go all out and remortgage your house for an absolute beast—but you'll end up playing the same game of *Cyberpunk 2077* on both. Now that PC component prices are becoming more reasonable and there's a chance of getting hold of an Xbox Series X, I decided to visit the age-old PC vs. Console gaming debate in my feature on page 44. Having ditched my consoles last year in favor of a gaming laptop, I thought this would be a one-sided contest, but as I revisited the PS5 and Xbox Series consoles, I found plenty of reasons to play on all of the different formats. I hope my feature encourages you to grab the controller and get playing, no matter what your machine of choice.

Speaking of letters, we also have two brilliant features in this issue that go deep on the sort of tech stories I get the most requests for. On page 32, Jeremy Laird looks back at how AMD nearly went to the wall, only to come back from the brink and deliver one of the most extraordinary comebacks in tech history, both in terms of its products and stock market performance. And on page 54, Jarred Walton casts his eye over the latest generation of GPU-powered supercomputers to see what they're capable of, what AI-driven tasks these monster machines could perform in future, and who might win out of Nvidia, Intel, and AMD.

It'll be a struggle to top the three-build special, but I'm thinking about future cover features on topics such as couch gaming, budget builds, and dream machines, and would love to know what you most want to see. Email me at editor@maximumpc.com. As always, I love all feedback, good and bad!

Enjoy the issue!

Guy Cocker

*Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

# THE NEWS

# AMD refreshes three 6000-series GPUs

## Flagship GPUs launched ahead of RDNA 3 this fall

**WE NOW HAVE** a new best-ever Radeon graphics card, the RX 6950 XT. This three-fan monster has, AMD says, "been engineered to deliver the ultimate 4K gaming experience". Basically a refreshed 6900 XT, it is built around the same 7nm Navi21 GPU with 5,120 Stream Processors and 80 Compute Units. It is clocked faster though, with the game clock jumping from 2,015MHz to 2,100MHz, a four percent bump.

While we wait for RDNA 3, AMD has refreshed three cards, including its top dog, which is now bigger and meaner.

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The maximum boost speed gains 60Hz to 2,310MHz and although memory is the same, 16GB of GDDR6, it's now 18Gbps rather than 16Gbps, while memory bandwidth rises from 512GB/s to 576GB/s. AMD quotes the 'effective' memory bandwidth using the Infinity cache, now 1,793.5GB/s, up from 1,664.2GB/s. That's some useful extra bandwidth. All of these changes have pushed the power consumption to 335W, making this a physically big, and hot card.

How fast is it? Turn to page 74 for our full review, but AMD references figures across eight games running at 4K, with the new flagship averaging an extra five frames per second. It's a marginal improvement but faster is better. Running games at 4K has never been the Radeon line's strength, whereas Nvidia's Ampere architecture does well at this. While the 6950 XT has the same GPU as the 6900, it's essentially the best Navi21 GPUs AMD could find. So if you plan on overclocking, this is the version you want.

AMD's reference model is $1,099. There are variations from third parties, generally with colored LED lighting, stylish enclosures, and a few other tweaks, which will cost more. The base price is $100 over the 6900 XT, but you get an equivalent percentage performance boost as the price increase. At least AMD hasn't milked the prices.

Two more new Radeon RX cards have been launched: the 6750 XT and 6650 XT (the 6800 is to remain untouched). Both follow the pattern of the 6950 XT, with some extra performance, but no major changes. For the 6750 XT, that means the game clock gains 71MHz over the 6700 XT to 2,495MHz, and that effective memory bandwidth gains 48GB/s to reach 1,326GB/s. Power consumption gains 20W to 250W. AMD's performance figures run the card at 1440p and show an average frame rate increase across its basket of games of over 9fps. The 6750 XT starts from $549 and sits somewhere between the GeForce RTX 3060 and 3070.

Lastly, there's the RX 6650 XT. Again, it has a faster game clock and more memory bandwidth than the 6600 XT. AMD pitches this card at 1080p gaming, with an average gain of 6fps. The 6650 XT starts from $399 and goes up against Nvidia's RTX 3060. All three will be sold alongside the existing range, so the only card we lose is the 6600 XT.

Essentially, AMD has taken advantage of the binning process to maximize the potential of its existing RDNA 2 silicon. This is the final flourish of the top-tier RDNA 2 cards before the arrival of the RDNA 3 GPU, which should change things considerably.

This is expected to land with the new Zen 4 processors this fall. This is a process change (7nm to 5nm), as well as a shiny new architecture. It will launch on high-end cards first, replacing the 6900 and 6800-series. Mid-range cards and below will continue with RDNA 2 chips, albeit with a refresh and a process change.

AMD engineers are confident they have something special. When RDNA 3 lands it will be thrown into battle with Nvidia's 'Lovelace' rival. It's a short wait before what's certain to be quite a fight. **–CL**

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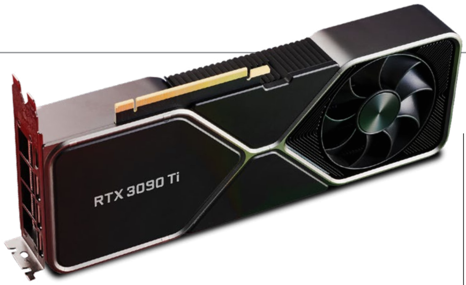
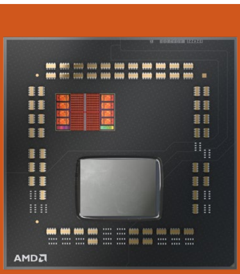
# GEFORCE RTX 40-SERIES SHAPES UP



**THIS SUMMER,** we'll see Nvidia's next-gen RTX 40-series, armed with the first Ada Lovelace GPUs. The earlier than expected date means it won't launch at the same time as AMD's RDNA 3 cards, which no doubt suits both companies. The new GPUs range from the 18,432 core AD102 to the more modest 3,072 core AD107. Details are sketchy, but the first three cards will be top-tier ones, including the RTX 4090 with the AD102 and 24GB of GDD6X: the same memory configuration as the current RTX 3090 Ti (above). Power consumption could be 450W, not as insane as earlier rumors. We're promised an epic performance, with up to twice the horsepower of the RTX 3090. The RTX 4080 and 4070 will use their own GPU dies, rather than cut-down ones, and both get memory upgrades, 16GB for the 4080, and 12GB for the 4070. We'll have to wait for the 4060 and 4050, however. It appears the battle for graphical supremacy will start at the top.**–CL**

## EIGHT ZEN 3 CORES IN A CHROMEBOOK



**TRADITIONALLY WITH** AMD processors, there's been a gap between the desktop and mobile markets. That gap is starting to close and AMD is bringing the latest 5000-series Zen 3 processors to Chromebooks with four new 15W chips. This will be quite a jump in performance from the last Chromebook chips, the Zen+ 3000-series from 2020. The top chip is the Ryzen 7 5825C, with an eight-core heart, a world-first for the Chromebook. It has a base clock of 2GHz and a maximum boost to 4.5GHz. Below this are the Ryzen 5 5625C and two Ryzen 3s, the 5425C and 5125C, with six, four, and two cores respectively. You also get improved Vega graphics and double the L3 cache of the previous generation. AMD estimates they will be between 67 and 107 percent faster than the previous Zen+ chips. The usual partners are busy building new systems, including HP with the Elite c645 G2 and Acer with the Chromebook Spin 514, both of which are due this summer. This means Intel's Tiger Lake chips face some much stiffer competition. **–CL**

## Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

### TRIUMPHS

✓ **PLASTIC-EATING ENZYMES**
Researchers at Texas University found proteins that break down plastic. 'Depolymerisation' can turn landfill into useful material.

✓ **EARLY APPLE TO AUCTION**
A rare 'first batch' Apple-1 is to be auctioned. Last time a similar rig was sold, it fetched $500K.

✓ **IT'S ALIVE**
Researchers studying ancient rock salt think some microbes inside the 830million-year-old crystals might be alive.

### TRAGEDIES

✗ **CRASHED FOR LIKES**
The FAA ruled that YouTuber Trevor Jacob crashed his light aircraft for content and took away his pilot certificate.

✗ **8K FLOPS**
Content is king, which is why 8K TVs made up just 0.15 percent of worldwide sales last year.

✗ **STABLECOIN ISN'T**
Cryptocurrency Terra Luna is almost worthless after a $45bn crash. The stablecoin to which it was coupled lost its dollar peg.

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# INTEL'S MOBILE MONSTERS

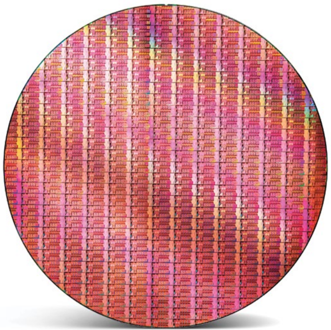
## Fancy a desktop chip in your laptop?

**INTEL HOLDS LOTS** of events, one of which is Intel Vision, where it shows off its latest wares. This year's event brought HX versions of the Alder Lake 'extreme performance' mobile chips, which join the U, P, and H versions. These are the most powerful mobile processors Intel has made and the first to offer 16 cores in a laptop. HX chips use Ball Grid Array packaging and look like thin desktop chips. If you want to do away with your desktop and have a high-end laptop instead, these are the chips—Intel is using words like 'desktop-caliber' and 'mobile workstations'.

Initially, there are seven new chips, the top one is the Core i9-12950HK, which has 16-cores, including eight dual-thread performance cores and eight efficiency cores. It has a base clock of 2.3GHz for the P-cores and a maximum boost clock of 5.0GHz. One down is the Core i9-12900HX, then there are three Core i7s, the 16-core 12850HX and 12800HX, and the 12650HX, which loses four efficiency cores. Below these are two Core i5s, the 12600HX and 12450HX, which drop to four performance cores and either eight or four efficiency cores. There's support for DDR5-3200 and 4800, as well as 16 PCIe 5.0 lanes, the first mobile platform to reach version 5.0. Base power consumption is 55W across the range, increasing to 157W on full tilt. All carry integrated Xe graphics but they are designed to partner with dedicated GPUs.

That brings us to the Arc Alchemist project, which has hit more delays. This must be annoying for Intel, as a combined HX and Arc launch would have made waves. We'll see the Arc mobile GPUs in late summer but it'll be a while before you can order a discrete card for your desktop. Intel hasn't yet said how much these high-power laptop engines will cost. **–CL**

**Alder Lake mobile chips are desktop chips, with 16 cores and a 5.0GHz boost clock.**



# FBI SEARCHES DATA WITHOUT WARRANTS

## And Facebook's data collection is a mess

**THE NATIONAL** Intelligence Office publishes an Annual Statistical Transparency Report. Last year's contained this gem about the FBI: it made "fewer than 3,394,053" searches of US citizens' data. These searches are supposed to require a warrant, yet none were preceded by one. This requirement had been side-stepped by reference to an amendment of the Foreign Intelligence Surveillance Act which allows such searches in pursuit of threats emanating from outside the US. It transpires that many of the searches were to find out who those foreign interests were trying to target. The result is a regular US citizen can earn a digital frisk from the FBI, with no warrant or warning.

Meanwhile, it transpires that your data isn't exactly carefully managed either. A study by Meta was prepared, prompted by prospective legislation, on how it uses data gathered through Facebook. The resulting report found its way online (the irony!) and it seems Meta isn't ready to comply with first-party data laws (data collected directly from customers) because its systems were never designed to allow for this. Put simply, it has a vast pool of data, all mixed with no way of separating the various types. Officially, Facebook doesn't sell your data—it says so on its Help pages. This is dissembling though, as it's easy to argue that selling targeted advertising is effectively the same as selling data.

We all have an increasingly complex and revealing amount of data gathered on us, and we have precious little control over who sees it or how it is used. However, there is a lot of international privacy legislation in the pipeline, so it's going to be a thorny issue soon. If the report on Meta's situation is typical, then the industry really isn't ready, nor is the FBI. **–CL**

# Nvidia's anti-crypto limiter broken

**THE MODERN GPU IS A WONDER**, which unfortunately has made it an ideal chip for mining cryptocurrencies. So with many of our best cards being snatched away and put to work in sheds to mine cryptocurrency, Nvidia implemented a Lite Hash Rate system for most of its 30-series cards last year. This throttled the GPU by 50 percent if it detected it was being used in Ethereum mining. However, it wasn't long before work started to break this, and now the mining outfit NiceHash (a broker of hash power and a crypto exchange) has announced that it has managed to circumvent the limitation, although it hasn't unlocked every card yet. So, you can now use your racks of Nvidia cards to mine Ethereum at full speed again. It's no surprise that the protection was broken, only that it took this long to do it.

Meanwhile, Nvidia has been handed a $5.5 million fine from the Security and Exchange Commission for not disclosing how many cards went to miners, allegedly putting these sales in the gaming category. This was during the Ethereum boom of 2018, while it was busy pushing its dedicated mining chips. Nvidia hasn't admitted the allegation but is paying the fine anyway. Ethereum is due to change to proof-of-stake soon and, as a result, the CFO of Asus, Nick Wu, predicts that "graphics cards will come back to gaming applications". The decline of old-school proof-of-work coins can't come soon enough, given the silicon and power resources required. **–CL**

**Limiting a card's mining power was going to be a challenge to hackers, though Nvidia's worked for a while.**

## The passing of passwords

The first Thursday in May is World Password Day and, this year, FIDO (Fast IDentity Online), an alliance that includes Google, Microsoft, and Apple, launched an initiative to end the use of passwords. Why? Because an estimated 80 percent of data breaches are caused by passwords being broken and a considerable amount of time, effort, and money is being lost resetting old passwords.

So what's planned instead? Currently, there are three sets of specifications all linked to a single master key on your smartphone. To identify yourself, unlock your phone and use a code sent by SMS, with a cloud backup if you lose your phone. It sounds like a good idea, though linking to an item so easily lost also seems risky. **–CL**

## No more iPods

Apple is about to stop making the iPod so, if you want one, you have until current stocks are exhausted. At its height, the iPod was the gadget to have, complete with its iconic white earphones, but as soon as the iPhone appeared in 2007, its days have been numbered—the real surprise is that it made it this far. The growth of streaming music didn't help either, as there's a whole generation that now looks upon CDs as amusingly 'retro'.

The iPod first appeared in 2001, but it wasn't the first portable digital music player—the Diamond Rio preceded it by three years. However, Apple did it so much better that the iPod became synonymous with music players, even giving us the term 'podcast'. Apple sold 450 million of them in all, a highly successful run. **–CL**

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Jarred Walton

## TECH TALK

# AMD Seeking Zen, Round Four

**THE PROCESSOR DEVELOPMENT** cycle takes a long time, from initial goals and planning through early simulations and hardware revisions. When AMD started working on the Zen 4 architecture, switching to a DDR5-exclusive memory controller probably seemed like a sensible choice.

Now, after the supply chain disruptions of the past two years, requiring DDR5 memory for socket AM5 could prove a serious liability. Just like Intel was the first to support DDR3 and DDR4 memory, Intel started supporting DDR5 and LPDDR5 with Alder Lake in late 2021. In theory, the transition to DDR5 should be underway by the fall, with improving supply and decreasing prices. Unfortunately, things haven't gone quite according to plan.

Unlike DDR4 and earlier variants, DDR5 makes a big change by moving the voltage regulation and power management integrated circuits (PMICs) onto the DIMM modules. This helps DDR5 reach higher speeds but also increases the cost by a not insignificant factor. More critically, small chips like the PMICs have been hit hard by the supply chain disruptions, leading to even higher prices.

When Intel decided to include both DDR4 and DDR5 support in its Alder Lake CPUs, it further delayed the widespread adoption of DDR5. Currently, it's possible to get a 2x 16GB DDR4-3200 kit for around $100, while the least expensive 2x 16GB DDR5-4800 kits cost over twice as much. Perhaps Intel has learned a thing or two from being the first to adopt new memory types in the past. Further complicating matters, DDR5 platforms for Intel CPUs aren't significantly faster than DDR4 solutions. That makes it difficult to justify the hefty premium, particularly when considering lower-tier Core i5 and Core i3 parts.

> The Zen 4 architecture will power AMD's upcoming processors, which will require DDR5 memory.

AMD likely decided to simplify its Zen 4 designs by sticking to only one type of memory, DDR5. Perhaps that will be of some benefit when it comes to performance, as the architecture can cater specifically to the latencies and speeds of DDR5 memory. But it will also make it difficult for AMD to deliver Zen 4 parts that can target budget or even midrange buyers. If the cost of an Intel Core i5 with 32GB of DDR4 ends up being $100 less than the price of a Ryzen 5 with DDR5, that's going to be a tough upsell.

But let's not count AMD out of the running just yet. Besides the 'Raphael' CPUs that will become the Ryzen 7000 series, AMD has also revealed the 'Dragon Range' and 'Phoenix' families of processors that include integrated graphics. AMD claims these will be the "pinnacle of gaming performance" and will feature the highest core and thread counts ever for mobile parts, along with more cache — perhaps 3D V-Cache, or possibly just larger L3 sizes enabled by TSMC's 5nm process technology. DDR5 could also prove beneficial for integrated graphics, where more memory bandwidth tends to translate directly into higher gaming performance.

© AMD

The bigger question will be how Zen 4 stacks up against Intel's dual-pronged P-core and E-core assault, coupled with continued DDR4 and DDR5 memory support. The next generation Raptor Lake CPUs could double the number of E-cores on the highest end parts, but as the Core i7-12700K and Ryzen 7 5800X3D prove, eight faster CPU cores in the right design are still more than sufficient.

Perhaps Zen 4 will be like Zen 3 and deliver such great performance that the higher cost will be warranted, but Intel currently dominates the budget, midrange, and high-end sectors with Alder Lake and doesn't look to be backing off any time soon. Whatever happens, this fall is shaping up to be a doozy in terms of new hardware promising ever-increasing levels of performance. Bring it on!

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

# THE LIST

## THE TOP FIVE WIRELESS GAMING MICE

**ESPORTS PLAYERS USUALLY** demand wired mice for reduced latency and improved responsiveness, but for everyone else, there are wireless mice. If you spend hours at your computer working or gaming, there's nothing quite like the luxury of being able to navigate unencumbered by a mouse cable. Our selection this month covers the best mice for comfort, features, and style, all across a range of budgets. Whether you're looking for your first wireless mouse or an upgrade, these are the ones to check out.

5

### HYPERX PULSEFIRE DART

HyperX has a track record of making great products at a competitive price, a tradition we're pleased to see has been continued with the Pulsefire Dart. It features one of the simpler designs of the mice on test here but it feels great to use, has an incredibly responsive 16,000dpi sensor, and will charge using a Qi wireless charger if you have one, or a cable if not. It even has RGB lighting, which is controlled via HyperX's software. **$69, www.hyperx.com**

4

### ROCCAT KAIN 202 AIMO

Roccat's mouse wins in terms of accuracy with its 19,000dpi sensor, although bear in mind you can't change that if it's too responsive for your tastes.
On the plus side, it boasts both 2.4GHz Wireless and Bluetooth connectivity, making it perfect for running double duty across desktop and laptop computers. It's also pleasingly lightweight, has a distinctive honeycomb RGB lighting, and, overall, feels built to last.
**$110, www.roccat.com**

3

### RAZER DEATHADDER V2 PRO

Razer's mouse has that reassuring feel of quality you expect from the brand. It's not lacking in features, with 70 hours of battery life, HyperSpeed wireless tech, and a button on the base to switch between custom profiles that adjust sensitivity and RGB lighting. Unlike the Logitech G502 mouse, it doesn't have an infinite scroll wheel and won't charge over Qi or a specialized mouse mat. **$130, www.razer.com**

2

### LOGITECH G502 LIGHTSPEED WIRELESS

This is the ultimate wireless mouse flex—a mouse that charges itself while you're using it. You need the Logitech G Powerplay Wireless Charging Mat ($110), but you'll never have to worry about a dead mouse again. The G502 Lightspeed Wireless has a 16,000dpi sensor for incredible accuracy, customizable buttons, and 2g and 4g weights that can be added if required. **$110, www.logitechg.com**

1

### CORSAIR DARK CORE RGB PRO SE

Corsair's wireless mouse can also charge itself using a mouse mat, in this case, the Corsair MM1000 ($80). But it gets extra points because it's also Qi-compatible, meaning that if you don't want to buy a special mouse mat, you can just buy a cheap wireless charger or use the one you probably already own. The Dark Core RGB Pro SE looks great, has a brilliant 18,000dpi sensor and Bluetooth connectivity, making it the ultimate feature-packed mouse. **$70, www.corsair.com**

© HYPERX, ROCCAT, RAZER, LOGITECH, CORSAIR

Jeremy Laird

## TRADE CHAT

intel
Xeon Phi™ Coprocessor

*Above:* **Intel's Larrabee never made it to market as a graphics card.**

© INTEL

# The danger of dabbling in Alchemy…

**CAN INTEL FINALLY DO IT** and produce a competitive graphics card? The answer should already be in hand. But the release of higher-performing versions of Intel's Arc graphics cards is likely to be delayed. For how long Alchemist could be held back isn't clear, but from a company with a dismal record for delivering dedicated graphics products, it hardly bodes well.

We've been here before, of course. The most recent Intel graphics debacle was the Larrabee GPU. Intel popped a cap in that project back in 2009. At the time, Intel said it wasn't dead, merely that the first chip in the new family of Larrabee graphics architectures had fallen behind sufficiently for it to no longer be viable as a retail product.

But we all knew it was curtains. With Alchemist in mind, it's scary to recall just how close Larrabee got to launch. It had been integrated into fully working prototype graphics boards, several of which inevitably ended up on eBay. Ominously, Larrabee was just a few months away from release, if only it had performed up to expectations.

Mercifully, the similarities between Larrabee and Alchemist only go so far. Larrabee failed in large part thanks to a radical design using a swarm of tiny x86 cores rather than conventional graphics shaders. Alchemist is a much more conventional graphics design, the basic competence of which is already proven in integrated form as found in Intel's latest 12th Gen processors, even if it's not yet been shown to scale up to a larger and much higher-performing dedicated GPU.

But from where I'm standing, two closely related issues threaten to bring Alchemist down, and maybe take the whole Arc project with it. Firstly, Intel picked one heck of a time to enter the GPU market. All indications are that both AMD and Nvidia are set to at least double performance with their new graphics products, codenamed RDNA 3 and Lovelace respectively, when they arrive later this year. That kind of huge generational increase hasn't happened in, well, pretty much a human generation. Meanwhile, the latest leaked info indicates the highest performing version of the first-gen Arc only has the grunt to take on the Nvidia RTX 3060.

> If Alchemist ends up sharing shelf space with RTX 4060 rather than RTX 3060, it's toast.

Had Alchemist hit its launch window, which may have been intended for around this time last year, taking on the RTX 3060 would have been dandy. The reality, after all, is that the bulk of gamers aren't buying more expensive boards like the RTX 3070 and 3080, let alone the megabucks 3090. But as the months tick by, the new RTX 4060 and its AMD rival grow ever closer, narrowing Intel's window of opportunity before the competition is suddenly twice as good.

The other issue is driver quality, which may be a major factor in Arc's leisurely wander towards retail availability. It's a tricky balance to strike, setting a timely launch against the PR impact of launching a product with patchy stability and compromised performance. But if Alchemist is delayed so long that it ends up sharing etailer shelf space with RTX 4060 rather than the RTX 3060, it's positively toast.

Speaking of dismal records, on anything outside its core competence of high-performance x86 processors, Intel doesn't seem to be able to get the job done. Its highest-profile failure has been getting into smartphones. But over the years, I've sat through countless demos involving subdivisions at Intel, from LCOS (Liquid Crystal on Silicon) projector tech to medical diagnostics, only for the project to fizzle, fold, or be flogged to the highest bidder.

And what is going on with Optane, the non-volatile memory that was somehow supposed to take over from both flash and RAM? It's not entirely dead but hasn't been the massive game-changer we were led to expect. Maybe I'm jumping the gun and Alchemist will be just fine. Maybe its successors Battlemage and Celestial, due out in 2023 and beyond, will take the fight to AMD RDNA 3 and Nvidia Lovelace across a broader swathe of the market. But I'm definitely beginning to get worried.

Six raw 4K panels for breakfast, laced with extract of x86… Jeremy Laird eats and breathes PC technology.

# DOCTOR

THIS MONTH THE DOCTOR TACKLES…

## > Upgrading NAS
## > HDMI without wires
## > Dual-boot and EFI

### NAS upgrade query

I'm looking at buying or building a NAS. In the past, I set up and used WD Reds in a five-disk Synology (DS1518+), configured in a Synology RAID setup. I was happy, but that was six years ago, and the technology has changed a lot. It would be great if you could do a custom NAS build or a comparison shootout between prebuilt units—actually, both would be ideal.

I need a solution that provides scalability, reliability, and easy usability, especially for unskilled users. This would be for personal data storage and backup and not for an enterprise application, however, I would still desire good throughput speeds. Would spinning disks still be the way to go? SATA SSDs? Or is it possible to make an ultra-small form factor using M.2 SSDs?

**—Jack Jordan**

**THE DOCTOR RESPONDS:** The simplest solution would be to stick with what you know and upgrade to a new Synology. That's because components for low-powered self-build models are incredibly hard to source right now—mini-ITX mobos sporting embedded low-powered Pentium and Celeron chips, such as those showcased by ASRock (www.asrock.com/mb/index.asp#Intel CPU) are near-impossible to find, and that's before you go hunting for a suitable chassis to house them in. Proprietary models such as those offered by Synology, QNAP, and Asustor are optimized for NAS use, so you'll have more robust RAID support, for example. For a closer look at all available Synology models, search through its NAS selector tool (www.synology.com/support/nas_selector) to see which models it recommends based on how you will use it.

When looking for comparisons with your old NAS, one particular model caught our eye: the $699, five-bay DS1520+ (www.newegg.com/synology-ds1520/p/N82E16822108747). Launched in 2020, it's powered by a modern Gemini Lake Refresh CPU (the Celeron J4125) along with 8GB RAM. Connectivity is handled with no fewer than four 1Gbps LAN ports (supporting link aggregation to maximize throughput), plus two USB 3.2 Gen 1 ports and two eSATA ports for attaching external devices. That may be overkill, in which case, the lower-spec'd DS420+ is $200 cheaper. It's powered by an older Celeron J4025 CPU, 2GB RAM (expandable to 6GB), two 1Gbps LAN ports, and four drive bays instead of five.

This leads neatly to your final question about which disks to choose. Spinning disks remain the most cost-effective and reliable storage medium, but both DS420+ and DS1520+ models also come with two NVMe slots that allow you to add NVMe SSD drives as a cache to boost overall performance.

### Wireless HDMI?

In the April issue, Gary Lavery wrote to the Doc and asked if Microsoft could create virtual TPM 2.0 functionality to allow Windows 11 to run on older hardware. The Doc responded that if this were possible, it would have already happened. I'd like to point out that it *is* possible but the reason it hasn't happened—and won't happen—is because Microsoft is responsible for the code requiring the TPM 2.0. However, I'm grateful for the registry workaround the Doc supplied in his answer.

Also, in the May issue, Gary Dent inquired how to hide a laptop or computer components behind the TV mounted on the wall in his kitchen. There are HDMI Bluetooth adapters made by TIMBOOTECH that connect an HDMI computer output to the HDMI input on the back of the TV. The ones I saw on Amazon support 4K.

**—Joe Saway**

**THE DOCTOR RESPONDS:** You're right Joe, but in the Doc's (admittedly weak) defense, he did point out how to virtualize a TPM 2.0 chip in Hyper-V to run Windows 11 on older hardware in his original answer, thereby insinuating it could be done.

Regarding your second suggestion, it's a good call, in theory, but there are two major stumbling blocks to consider. The first is simply price: TIMBOOTECH's options cost $130 a pop (others are even more expensive). That might be a price worth paying if you're wanting to transmit signals between rooms (say streaming from your office's

↘ submit your questions to: doctor@maximumpc.com

PC to the big-screen TV in your den), but it's harder to justify in a scenario where a 50cm HDMI cable should suffice. The other issue with wireless HDMI is the latency of the signal—that's not necessarily a problem when streaming or performing everyday computing tasks, but gamers are likely to find the lag is too great to make gaming practical. A quick glance at the mixed reviews on Amazon confirms this to still be a major issue.

## Clear event logs

I've asked two past editors whether it's possible to have the Windows Event Viewer cleaned of errors and warnings. They both said that it was and that they would do an article on this in the future. Well... maybe the future is now? I would welcome this. **—Len Babin**

**THE DOCTOR RESPONDS:** No need for a full article, Len—simply open Event Viewer (press Win + R, type eventvwr and hit Enter), expand Windows Logs in the left-hand pane, then right-click each log and choose 'Clear Log' to delete them in turn. You'll be prompted to 'Save and Clear' or simply 'Clear' the current log; choosing the former allows you to save it in a variety of formats (including .evtx, which can be loaded back into Event Viewer) should you need to refer to it later.

If you're looking to clear all event logs quickly and without fuss, then you might think a clean-up tool like CCleaner (www.ccleaner.com) would come to the rescue. The fact is, despite offering a 'Windows Event Logs' option under Advanced in its custom cleaning section, the tool doesn't work with any version of Windows from 2018 onwards. Instead, press Win + R and type the following directory into the Run box before hitting Enter: %SystemRoot%\System32\Winevt\Logs\

This will take you to the folder containing those (and other) log files. They are easily identifiable by name, but remember—once deleted, you won't be able to look back on them for any troubleshooting help.

## Dual-boot conundrum

I have a problem that I cannot find the answer to. My Ryzen 5950X system has two 1TB Sabrent Rocket 4.0 NVME drives, plus a Samsung 970 EVO NVME and 8TB internal Seagate HDD. Currently, Windows 10 is installed on one of the 1TB Rockets. I wiped out everything on the second 1TB Rocket, planning to install Windows 11 on it in a dual-boot configuration while I dip my toes in and see if any of the applications I use have problems.

I created a USB flash drive and have installed Windows a million times, so am pretty familiar with the standard procedure. When the install got up to the point of copying the files over, I got an error: 'Windows Could Not Prepare the Computer to Boot Into the Next Phase of Installation'. I have tried to troubleshoot this message, tried new boot media, created install partitions to copy the files to with diskpart, formatted these from the command prompt while installing, and so on.

Once, I got slightly further before it bombed out with the same error as before. I've thought about removing all the drives except the one Sabrent Rocket I want Windows 11 on. I've also considered partitioning the Windows 10 drive and trying to install Windows 11 on the same physical disk, but it feels more and more like I'll have to just remove the drives, install Windows 11 and then live without being able to dual boot. Any advice? **—Shawn Rakestraw**

**THE DOCTOR RESPONDS:** By the time we spoke to Shawn, he'd decided to forego dual boot by simply swapping out the Windows 10 NVME drive for the Windows 11 one. His only reason for pursuing the dual-boot option had been the need for a fallback if a critical program proved incompatible with the new OS. That fear proved unfounded, so he was able to work around the problem.

The error message Shawn encountered could point to some form of corruption or issue with the EFI system partition. This partition is where key files are stored for booting installed operating systems, loading required device drivers for hardware used by firmware at boot time, and any programs designed to run before the OS is loaded.

Windows setup can also get confused if there are multiple drives connected to your system—you could try disconnecting all drives except those you need: your Windows 10 drive, the drive containing your EFI system partition, and the drive you plan to install Windows 11 on. With luck, that should get it over the finish line. If it works, reconnect your other drives and then carry on just as before.

To find out more about your EFI, its location, and what boot entries it contains—download the free version of Disk Genius (www.diskgenius.com). After opening the program, examine the list of drives and partitions in the left-hand pane to find the one marked ESP, which is your EFI system partition. If more than one ESP exists, choose Tools → Set UEFI Boot Entries to see what boot entries are stored in your BIOS/UEFI and, crucially, where they point to—the Disk and Partition entries should match the EFI in use.

Another option to consider would be to install the second operating system completely independently of the first as Shawn did, then reconnect both drives. From here, open Tools → Set UEFI Boot Entries in Disk Genius and you'll see each OS now loads from its own dedicated EFI system partition. They will both be listed as 'Windows Boot Manager' so it's wise to take the time to rename them to Windows 10 and Windows 11 before clicking 'Save current boot entry' each time to write the changes to your UEFI.

From here, you can switch between them using your UEFI/BIOS's own boot menu—first, navigate to the UEFI setup utility's Boot section to choose which drive you want to boot from by default—typically the latest version of Windows (so Windows 11 in this case).

Then, should you want to boot to your older operating system, make a note of the key required to access your UEFI boot menu when you first start your PC—F11 or F12 is a common keypress. Press this, then select Windows 10 from the menu to boot to that instead.

STATUS
DISK 1
DISK 2
DISK 3
DISK 4
DISK 5
Synology
DS1520+

Synology's DS1520+ ticks all our NAS boxes.

© SYNOLOGY

1080P
4K
NZXT
Fractal

# BENCHMARKI

## *Christian Guyton* is testing,

**WE'RE FINALLY DOING IT**, folks. For years now, we've been running the same set of benchmarking tests in our build tutorials and system reviews, and enough is enough. It's time for new numbers; specifically, the numbers that comprise our system zero-points for testing. No more will we be comparing shiny new gaming PCs to old hardware and testing years-old games. No, it's time to update our benchmarking process and make it relevant for 2022. We've actually wanted to do this for a while, but such a mammoth project takes time, and we've always had other pressing concerns. But no longer!

Sharp-eyed readers will no doubt already be aware that we have three sets of system benchmark zero-points, each targeted at a different resolution

# NG BUSINESS

## testing, one two three...

for gaming and general performance. That means we need three new PCs for comparison, one specced for 1080p, one for 1440p, and lastly a 4K gaming monster. We also have a separate set of figures for machines running on integrated graphics, but we'll be updating those in a future build.

Assembling three new systems inside of one issue is a big ask, but never let it be said that the *Maximum PC* team shies away from a challenge. Over these next 16 pages, we'll be walking you through the process of building these three rigs, discussing the hardware we're using, and of course testing the living daylights out of them. Going forward, you'll see the figures that we use in all of our featured PC builds and desktop system reviews. Excited yet? Let's get cracking.

# THE 1080p BUILD COMPONENTS

**CASE**

## NZXT H510

*WWW.NZXT.COM*

The ever-dependent H510 is one of our favorite PC cases, with a modern front I/O and a simple but clean design incorporating a glass panel and a PSU shroud. It's also an easy case in which to assemble a system and that will help us speedrun these three builds. • *RRP: $90* • *Street price: $80*

ROG STRIX
STRIX B550-F GAMING (WI-FI)
SupremeFX
M.2

**MOTHERBOARD**

## ASUS ROG STRIX B550-F WIFI

*WWW.ASUS.COM*

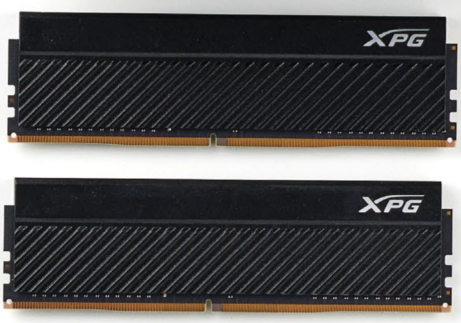
**A standard B550-chipset motherboard with all the basic features we'll need for this rig. Nothing fancy, just good support for all the rest of our components with PCIe 4.0 and an M.2 SSD heat shield. Okay, there's RGB too—so it is just a little bit fancy. •** ***RRP: $210*** **•** ***Street price: $179***

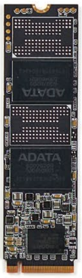
**GRAPHICS CARD**

## XFX SPEEDSTER QICK308 RADEON RX 6600 XT 8GB

*WWW.XFXFORCE.COM*

Yep, that GPU price debacle isn't quite over yet. Costs aside, the RX 6600 XT is an excellent all-rounder card for 1080p gaming, which uses AMD's new Navi 23 GPU, with 8GB of VRAM. The RDNA 2 architecture also leverages the nifty Infinity Cache feature to effectively boost the available memory bandwidth, which helps to improve 1080p performance • *RRP: $379* • *Street price: $647*





### POWER SUPPLY

## 450W CORSAIR CX450M 80+ BRONZE

*WWW.CORSAIR.COM*

With the relatively low TDP of our assembled components (thanks AMD!), we were able to choose an affordable power supply for this build. We've gone with the Corsair CX450M, which should offer sufficient total wattage and has a semi-modular design that will enable us to cut down on cable clutter.
• *RRP: $60* • *Street price: $60*

### MEMORY

## 16GB (2x 8GB) XPG GAMMIX D45 DDR4-3200

*WWW.XPG.COM*

**XPG's latest Gammix RAM is quite unassuming, with a simple black aluminum heat spreader and a speed of 3,200MHz. We're using a 2x 8GB kit, which has become the norm for many versatile PCs. That's enough memory to handle a variety of workloads without costing the world.**
**• *RRP: $60* • *Street price: $60***

### STORAGE

## 1TB ADATA LEGEND 840 M.2 SSD

*WWW.ADATA.COM*

The B550 chipset and Ryzen 5 5600X processor mean we have full PCIe 4.0 potential unlocked for this build, which is swiftly becoming the norm. The Legend 840 Gen4 SSD from ADATA is an ideal pick, and helpfully comes without the included heat spreader already attached, since we won't be using it. • *RRP $108* • *Street price: $108*

### PROCESSOR

## RYZEN 5 5600X

*WWW.AMD.COM*

**The defacto best chip right now for mid-range gaming builds, the Ryzen 5 5600X has freed itself from the mire of high CPU prices and is now available for a reasonable $230.**

**Six cores and 12 threads offer solid performance in both single-core and multi-core workloads, with a sensible 65W TDP and PCIe Gen4 support.**
**• *RRP: $300* • *Street price: $230***

### CPU COOLER

## AMD WRAITH STEALTH

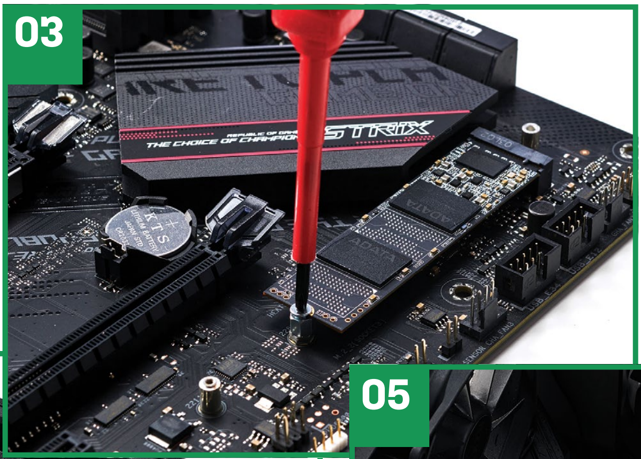
*WWW.AMD.COM*

While our 1440p and 4K builds will be enjoying AIO liquid coolers, the 1080p build is sticking with air cooling; namely, the Wraith Stealth stock cooler that comes bundled with the AMD CPU. Wraith coolers have always been a reliable choice, and while they're not really suitable for overclocking, they're perfectly sufficient for everyday use.
• *RRP $N/A* • *Street price: $N/A*

## Total: $1,207 (street price $1,364)

# THE 1080p BUILD STEPS

01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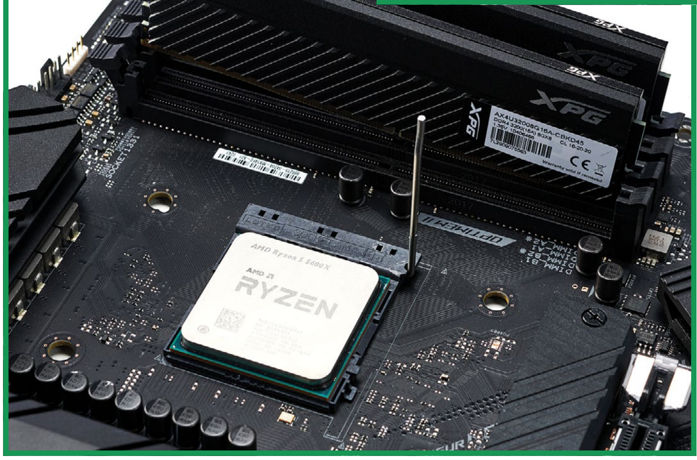
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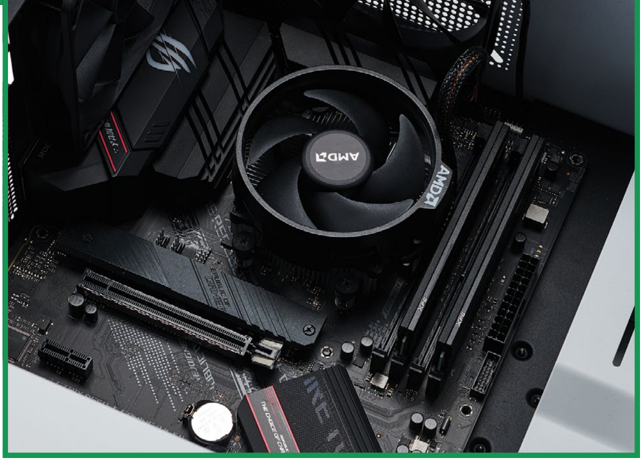
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01
### Stripped Back

As always, we start our build by stripping down the case to prep for assembly. We'll give you a super exciting sneak peek here: all three of our builds are going to start with this step. The NZXT H510 is a nice easy case for building in, so we don't anticipate any trouble here. Remove the two side panels by loosening the thumbscrews at the rear and lifting them off (the glass panel latches to the top of the PSU shroud on the bottom edge), but leave the fans in place; we don't need to remove them for this build. You can, however, remove the SSD drive mounts and the HDD cage, as we won't be using them and it will be beneficial to free up the space for cable management later.

02
### Processing Memories

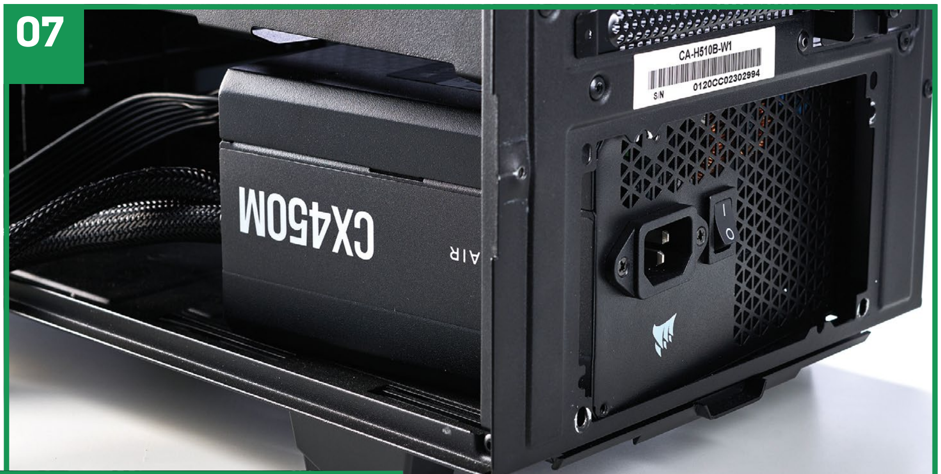
Ah, Ryzen. The easiest CPUs to install ever. Thanks for that, AMD. To fit our 5600X processor, all you need to do is lift up the metal retention arm and drop the CPU into the socket, ensuring that the gold triangle on one corner is lined up with the matching triangle on the gray plastic of the socket. Once it's in place, lower the retention arm and the chip will lock in. When you've done this, you can move on to the memory; this B550 board only has clips on one end of the DIMM slots, so open those up and fit the RAM to slots A2 and B2 (the fourth and second slots from the CPU, respectively). These DIMM slots are helpfully marked with an asterisk on the PCB, so you know which slots take priority.

03
### Heat, Shielded

The ADATA SSD we're using in this build does come with a metal heat spreader, but it's a bit on the weedy side compared to some stock spreaders we've seen, so we'll be using the motherboard's pre-installed heat shield instead. Using a small Philips-head screwdriver, carefully unscrew and remove the heat sink, then slot the SSD into the M.2 port. Remove the plastic from the sticky heat pad on the underside of the thermal shield, then press it down over the drive to hold it in place. Secure at both ends using the M.2 screws and you're all done.

04
### Lock, Stock, and one Smoking Cooler

The AMD Wraith is surely the 'old faithful' of stock coolers, offering a decent low-noise air cooling solution for your CPU, with an installation process so simple it could make liquid coolers cry. The B550-F motherboard should come with plastic brackets attached to either side of the CPU socket; remove these, then position the Wraith Stealth over the CPU so the four screws line up with the screw holes of the CPU backplate. With the cooler in place, secure it by first partially screwing in two opposing corners (you may need to apply some pressure) and then screwing down all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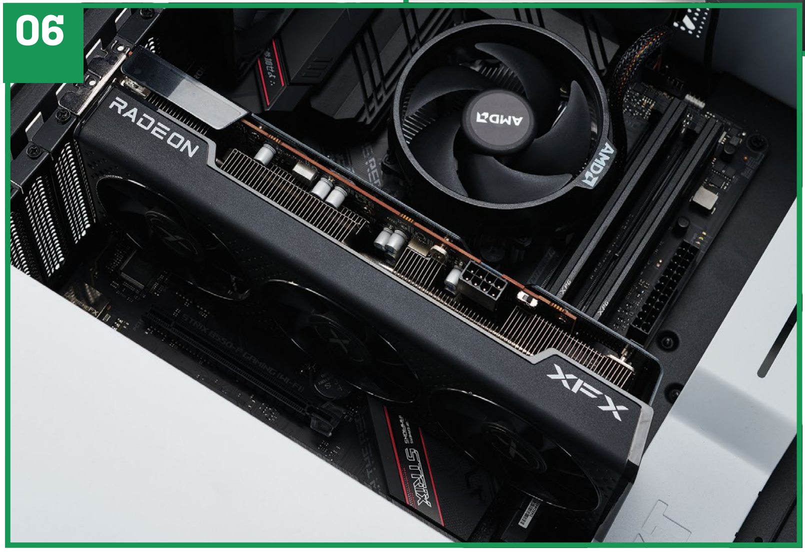
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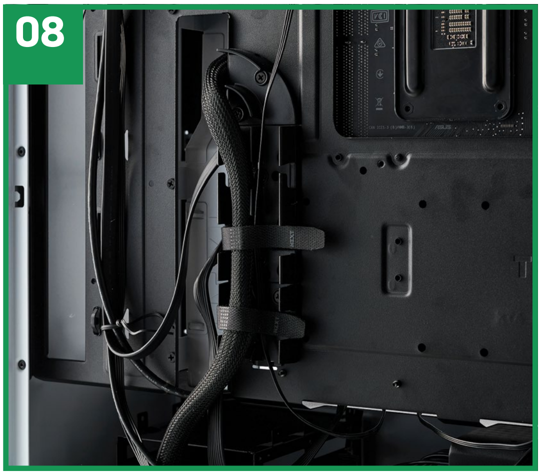

08

four corners until they stop turning. No need for extra thermal paste here; every Wraith comes with a thin layer preapplied to the underside.

## 05 Mount That Mobo

With most of our components now on the motherboard, it's time to situate that board inside the case. Lay the H510 on its side—being extra careful not to trap any loose cables from the front I/O—and gently place the motherboard inside, squeezing the rear I/O underneath the preinstalled case fan. This can be a tight fit, so if you're really struggling, simply remove the fan and return it to the case afterward. You'll know the board is in the right position when the rear I/O is lined up with the case and the central mounting peg is snug inside the screw hole in the center of the board. When you're happy with the positioning, secure it to the standoffs using the supplied screws.

## 06 Graphic Violence

Despite its triple-fan design, XFX's Qick RX 6600 XT isn't actually that big for a GPU, so it should fit comfortably inside this case. First, unscrew and remove the two blanking plates from the back of the case that line up with the PCIe slot closest to the CPU. Set these to one side (use a magnetic screw bowl) and carefully lower the GPU into the slot, ensuring that the plastic clasp is open. It should snap shut once the GPU is correctly installed. Once it's in place, use those screws to secure it.

## 07 Powering Up

The final component to install is, of course, the power supply. Since the Corsair CX450M is semi-modular and we don't have any fancy case accessories or SATA drives, you won't need to add much. The non-modular cabling accounts for the motherboard ATX and CPU power delivery, so you just need to add a single modular cable for the GPU, which will be marked 'PCIe'. With all the cables you need, gently place the power brick in its slot at the rear of the case beneath the PSU shroud, with the integrated fan facing downwards out of the case. Line it up with the rear port before screwing it into place.

## 08 Case Closed

The NZXT H510 has some nifty plastic channels behind the motherboard plate that allow for easy cable management, so we'll put them to use here; especially for the ATX power cable. Use ties to fix your cables in place as you route them around the motherboard, plugging in all the I/O cables as you go (we start with the fiddly power and reset switch cables, using the motherboard manual to check you have the right headers). When you're happy with your cables, return the two side panels to the case and screw them back on. Job done!

# THE 1440P BUILD COMPONENTS

**CASE**

## CORSAIR 4000D RGB AIRFLOW QL

*WWW.CORSAIR.COM*

The new QL edition of Corsair's 4000D Airflow case looks stunning in all-white, with loads of RGB lighting and a heavily-perforated case for maximum ventilation. It comes with three fans mounted at the front and one at the back, with a fan controller pre-installed behind the motherboard plate. • *RRP: $250* • *Street price: $250*

**PROCESSOR**

## INTEL CORE I7-12700K

*WWW.INTEL.COM*

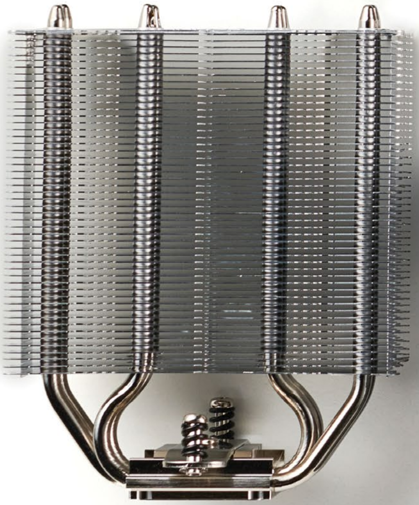
**Intel's revolutionary CPU architecture means we have eight 'performance cores' and four 'efficiency cores', the latter reducing the impact of secondary processes. The performance cores are hyperthreaded for a total of 20 threads.**
***• RRP: $402 • Street price: $382***

**STORAGE**

## SAMSUNG 980 PRO 1TB M.2 SSD

*WWW.SAMSUNG.COM*

**When it comes to SSD storage, you really can't go wrong with Samsung. The 980 Pro is the latest and greatest, offering stupid-fast read and write times along with smart thermal control for the NAND chip. We're using the version with an included heat sink since it's a bit bulkier than the heat shield found on the MSI MAG motherboard.**
***• RRP: $170 • Street price: $170***



**CPU COOLER**

## NOCTUA NH-U12S REDUX

*WWW.NOCTUA.AT*

Coolers that are compatible with the new LGA-1700 chipset for 12th-gen Intel chips are scarce, with many manufacturers offering retrofit kits for their coolers. Fortunately, Noctua's new 'Redux' edition of the NH-U12S air cooler supports LGA-1700 as standard, making it ideal for this build. • *RRP: $50* • *Street price: $50*

**MOTHERBOARD**

## MSI MAG B660M BAZOOKA DDR4

*WWW.MSI.COM*

**We're going to let you in on a little secret: we originally wanted a Z690-chipset board, but one with DDR4 support rather than DDR5 proved harder to get hold of, so we're running with the B660 chipset instead. Still, this is a dependable motherboard with a recently-improved PCB design that should ensure we get good performance out of the rest of our components.**
***• RRP: $160 • Street price: $160***

**GRAPHICS CARD**

## ZOTAC GAMING GEFORCE RTX 3070 TI AMP HOLO 8GB

*WWW.ZOTAC.COM*

The first of two GPUs from the lovely folks at Zotac we're using in this feature, the 3070 Ti AMP Holo is a three-fan card that hits its sweet spot at 1440p. The 3070 Ti uses super-fast GDDR6X memory (the cheapest 3000-series card to do so) and has DLSS and ray-tracing built-in, like all of Nvidia's recent releases.
• *RRP $599* • *Street price: $925*

**MEMORY**

## 16GB (2 X 8GB) G.SKILL TRIDENTZ NEO DDR4-3600

*WWW.GSKILL.COM*

**We're sticking with DDR4 throughout these builds, which may seem like an odd shout to some, but it's a fairer metric to compare other systems against for now. DDR5 memory is still super-expensive and not that widespread, so we've opted here to use G.Skill's RGB-lit TridentZ Neo memory, at a slightly higher clock speed than the XPG RAM found in the 1080p build.**
***• RRP: $115 • Street price: $115***

**POWER SUPPLY**

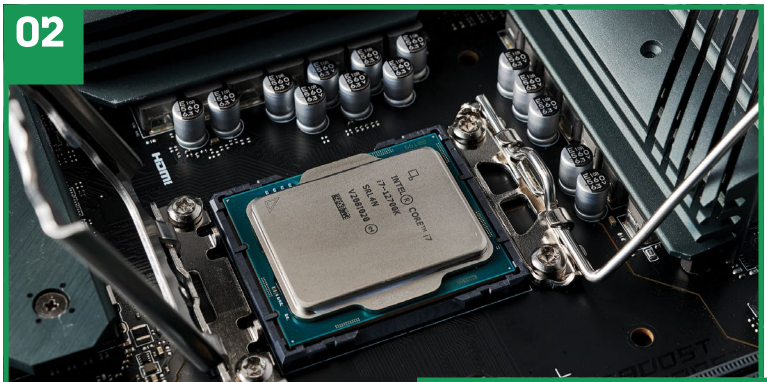
## 650W BE QUIET! PURE POWER 11 FM 80+ GOLD

*WWW.BEQUIET.COM*

A no-frills PSU from Be Quiet!, the Pure Power 11 FM offers a minimum rated efficiency of 88 percent along with a fully modular design that keeps cables to a minimum. Being from Be Quiet!, you can also expect the 120mm integrated fan to be optimized for near-silent operation.
• *RRP $100* • *Street price: $100*

## Total: $1,846 (street price $2,152)

# THE 1440P BUILD STEPS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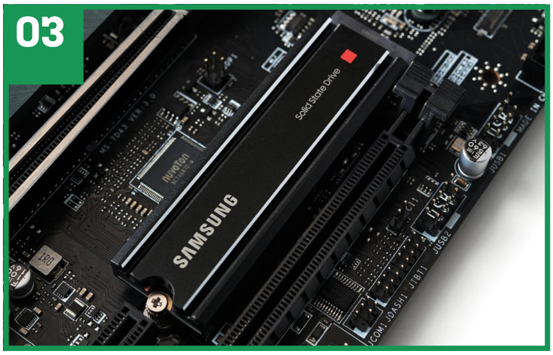
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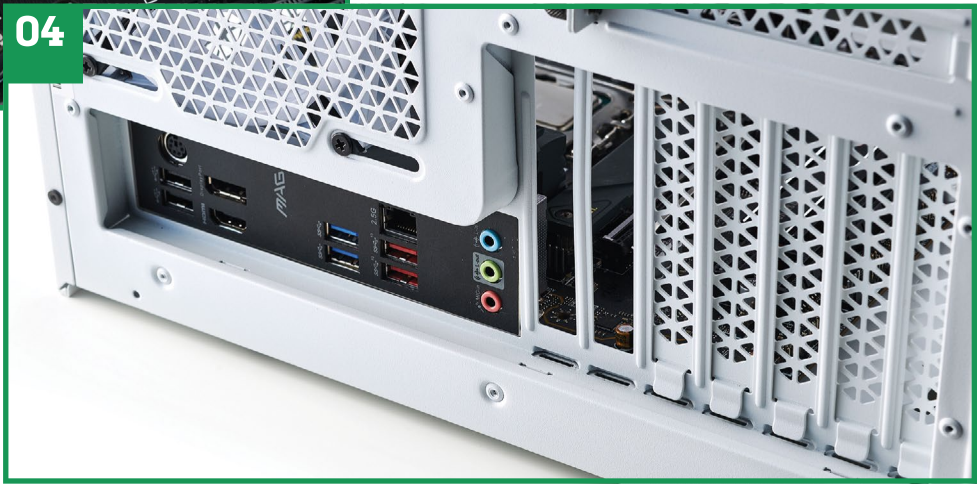
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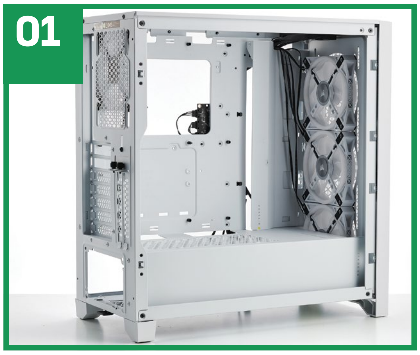

01

## 01 Case Open

Well, would you look at that: it's another case stripdown! As with the NZXT case, you can kick off this build by removing the two side panels (again, secured at the rear with thumbscrews) and also taking out the excess drive mounts and HDD cage. Inside that cage, you'll find a handy box of case accessories that contains the screws and standoffs you'll need for installing the motherboard, so put that to one side. You don't need to remove any fans from the case for this build either; the front panel of the Corsair 4000D is also removable with simple push-pins, but we'd actually advise leaving it in place to protect the case fans.

## 02 Socket Rocket

Intel CPUs are a little more fiddly to install than AMD ones, but it's still a mercifully tool-less process. All you have to do is free the spring-loaded retention arm from beneath its bracket, lift the entire bracket on its hinge, and drop the chip into place. You'll know it's aligned correctly if it sits snugly in the socket with no corners lifting up. Then you can lower the bracket back over the processor and return the retention arm to its original position; if you bought a new board, it comes with a black plastic cover that should snap off automatically when you lower the retention arm again.

## 03 Driving Force

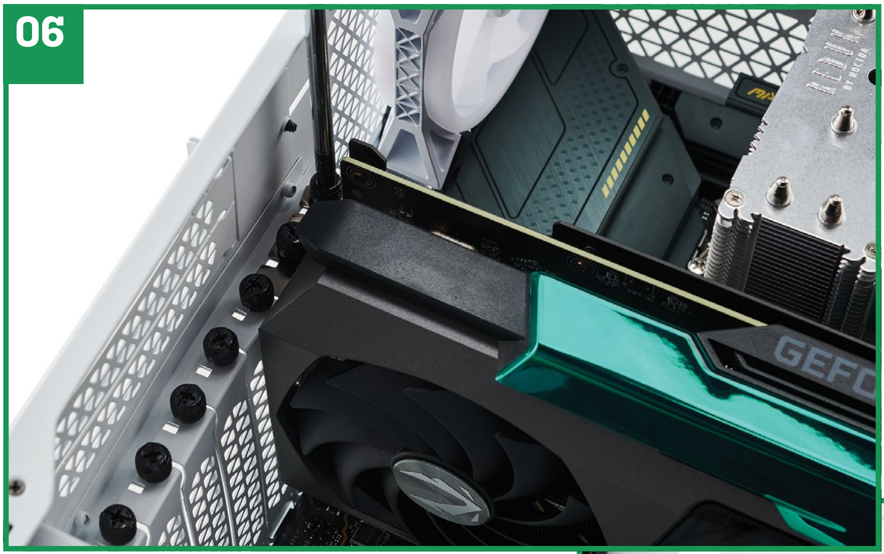
Unlike the ADATA Legend SSD, our Samsung 980 Pro comes with a beefy heat sink already attached to the drive. We'll be using this rather than any motherboard-integrated thermal solution, so all you need to do is fit the drive to the M.2 slot and gently push it down until the other end lines up with the M.2 standoff (you may need to move this to the right screw hole if it's already installed). Secure it with a dinky M.2 screw, then it's on to the memory. Same as last time, just open the DIMM clasps and push down each stick until it clicks into place, using slots A2 and B2.

## 04 Mexican Standoff

Unlike our other two builds, there's an extra step required for installing this B660 motherboard. Before it can be properly mounted, you will need to take two of the spare standoffs from the 4000D's accessory box and install them in the marked holes inside the case for mATX format motherboards. We strongly recommend using just your fingers to screw these in rather than pliers or another tool, since it's easy to scuff the screw holes with excessive force and that could lead to wonky standoffs, which nobody wants. With your additional standoffs in place, lower the motherboard into the case and line it up with the rear I/O slot before screwing it down. Be mindful not to trap the cable of the rear case fan under the board. You don't have to remove the unused ATX standoffs unless they offend your aesthetic sensibilities.

## 05 Noctua Animals

The patented SecuFirm mountings that come with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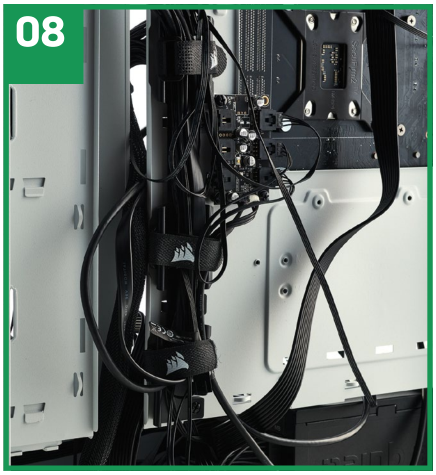
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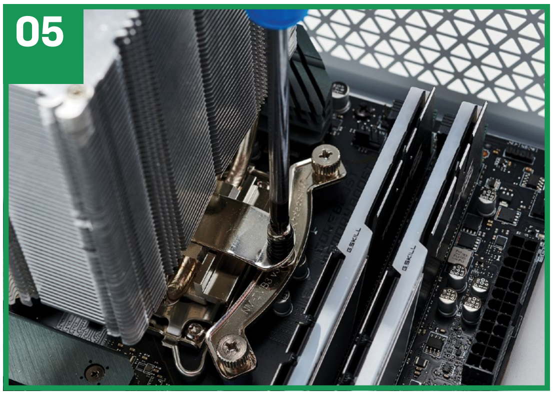
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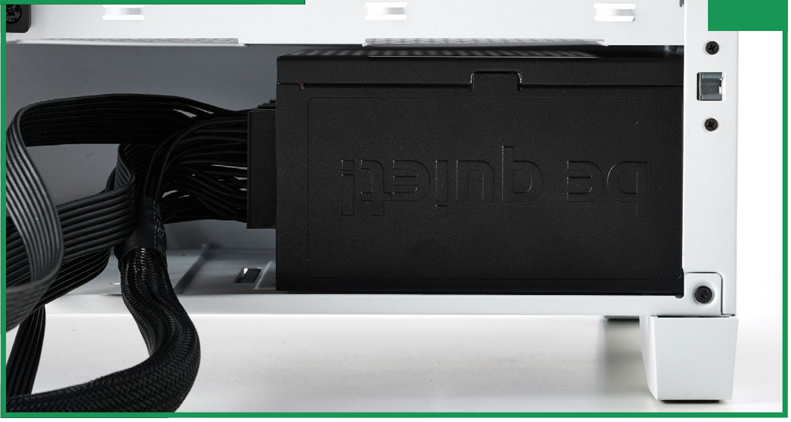
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Noctua coolers are pretty great, albeit sometimes tricky to install. Since the NH-U12S Redux can be mounted on just about any modern CPU, you'll need to make sure you have the right parts for an LGA-1700 socket. Follow the included instructions closely; you'll need to use position two for the bolts on the backplate and mounting bracket, and the blue plastic spacers. The fan may come pre-attached to the cooler tower, but you'll need to remove it for installation. Once the bracket is in place (don't over-tighten those screws) you can screw on the cooler tower and attach the fan using the metal hooks provided. Again, thermal paste should come pre-applied to the heat plate. Ensure that the fan is facing the front of the case for optimal airflow.

## 06

### Card Captor

Wow, these two Zotac GPUs are chunky boys. The 3070 Ti and 3090 we're using in this feature actually share the same integrated cooler and casing, making them near-indistinguishable. After checking we had the right card, we removed the blanking plates from the rear of the case and fitted the GPU into the PCIe slot closest to the motherboard, making sure the clasp on the slot was open. The GPU should click into place; apply a little pressure on the top until it does, but don't be too heavy-handed. Secure the GPU using the same screws that held the blanking plates in place. You can leave the Zotac GPU support bracket in the box; there's nowhere to install it in this case.

## 07

### Modular Makes It

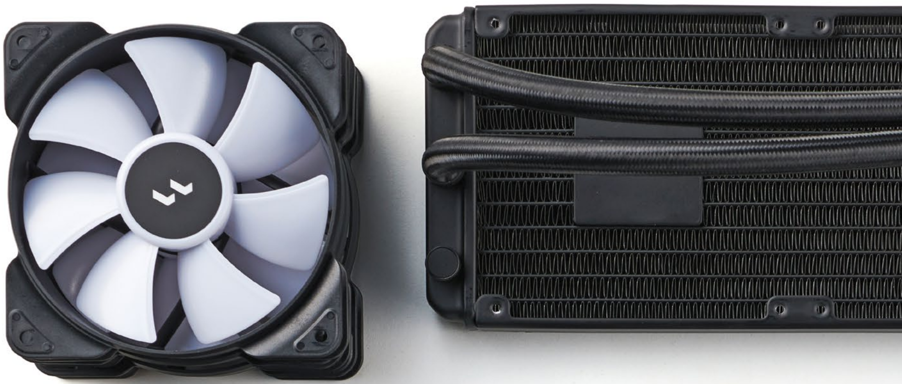
It's time to fit our PSU. This Be Quiet! power supply is fully modular, which means we'll need to manually fit all the power cables we need. It's not a particularly unusual selection; obviously, you'll need the motherboard ATX and CPU cables, along with two PCIe cables for that big old graphics card and, finally an accessory cable for the RGB fan hub included in the 4000D case. Connect all of these, then situate the PSU fan down inside the case underneath the metal shroud, so it sits on the foam sound-dampening pads. Secure it using four of the 6-32 hexagonal screws you can find in the case accessory box.

## 08

### Header Hoopla

As we mentioned earlier, the B660 mobo in this build wasn't actually our first choice. One of the reasons for that will become apparent when you try to plug in all your cables; there aren't enough fan headers on the motherboard to support all the fans in this case. With that in mind, we skipped the bottom front case fan since this would have the least impact on our overall cooling (although we did still hook up the RGB header for that sweet rainbow action). The rest of the cables from the PSU and case I/O shouldn't be too much trouble to install; there are plenty of cutouts for you to secure them with cable ties for a neat cabling job. When you're done, slap those case panels back on and you're good to go!

# THE 4K BUILD COMPONENTS



**CASE**

## FRACTAL DESIGN TORRENT

*WWW.FRACTAL-DESIGN.COM*

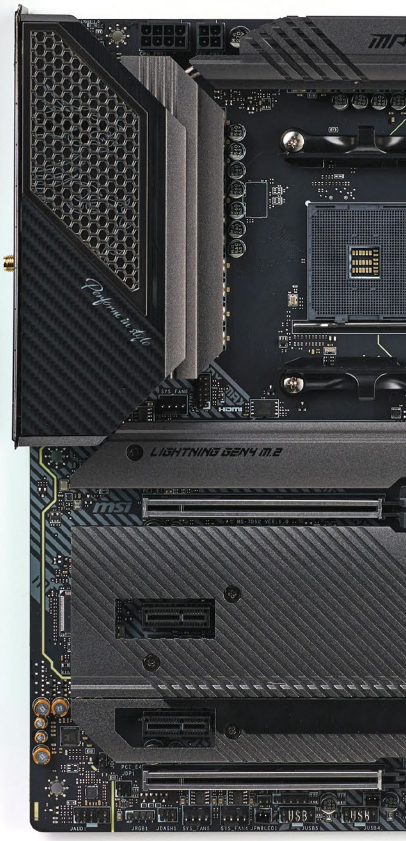
Indisputably one of the best full-tower cases on the market right now, the Torrent is a genuine triumph for airflow enthusiasts, thanks to its slatted front panel and aerodynamic top-mounted PSU shroud. It comes with five fans (two of which we'll need to remove) and a pre-installed Nexus P9 Slim fan hub, plus extra mounts for installing liquid cooling solutions. • *RRP: $230* • *Street price: $230*

**GRAPHICS CARD**

## ZOTAC GAMING GEFORCE RTX 3090 AMP EXTREME HOLO 24GB

*WWW.ZOTAC.COM*

**Setting aside the absurdly expensive 3090 Ti, the RTX 3090 is the de facto GPU of choice for anyone looking to dominate in some 4K gaming. There's a titanic 24GB of GDDR6X and more than 10,000 CUDA cores, which define this powerhouse of a graphics card, with our Zotac model boasting some natty RGB to boot. • *RRP: $1500* • *Street price: $1900***



**MOTHERBOARD**

## MSI MPG X570S CARBON MAX WI-FI

*WWW.MSI.COM*

The X570 chipset was a must for this build, and the Carbon Max Wi-Fi is one of the best-looking X570 boards around. A huge amount of heat spreaders ensure frosty-cool motherboard performance, backed up by Wi-Fi 6E, Lightning PCIe Gen4 support, and MSI's Audio Boost 5 technology for studio-quality sound. • *RRP: $340* • *Street price: $320*

**CPU COOLER**

## FRACTAL DESIGN LUMEN S36

*WWW.FRACTAL-DESIGN.COM*

Our high-end benchmarking build required liquid cooling, especially since the Ryzen 9 5950X doesn't come with AMD's Wraith air coolers. The Lumen S36 is a stylish number, with a sleek pump block that illuminates with a gentle RGB glow and three LED-equipped fans. • *RRP: $130 • Street price: $180*

**PROCESSOR**

## AMD RYZEN 9 5950X

*WWW.AMD.COM*

**AMD's top-end processor is a beast, packing 32 threads optimized for gaming. The Zen 3 architecture is power-efficient, with a base TDP of 105W in the 5950X, less than the Core i7-12700K in the 1440p build. The only thing it lacks is DDR5 support. • *RRP: $700 • Street price: $620***

CORE BOOST
DDR4 BOOST
MPG X570S
CARBON MAX WIFI
CARBON

**POWER SUPPLY**

## 860W FRACTAL DESIGN ION+ 2 80+ PLATINUM

*WWW.FRACTAL-DESIGN.COM*

We did contemplate springing for an 80+ Titanium rated PSU for the 4K build, but at that point, you're paying a lot of money for a marginal efficiency boost. Platinum it is, then, and the 860W Ion+ 2 is the final Fractal Design component going into this build. It comes with proprietary 'UltraFlex' cables, which the Swedish manufacturer claims are 'extra bendable'. • *RRP $170 • Street price: $170*

G.SKILL
TRIDENTZ
G.SKILL
TRIDENTZ

**MEMORY**

## 32GB (2 X 16GB) G.SKILL TRIDENTZ DDR4-3200

*WWW.GSKILL.COM*

**Look, 16GB is pretty much always enough memory for a build (unless you're planning on running hundreds of Chrome tabs), but we'd be fools not to boost it up for the 4K rig. As such, we've got 32GB of TridentZ RAM from our friends at G.Skill. No showy RGB lighting here, we're afraid, but let's be honest: performance matters more than looks.**

**• *RRP: $130***

**• *Street price: $130***

**STORAGE**

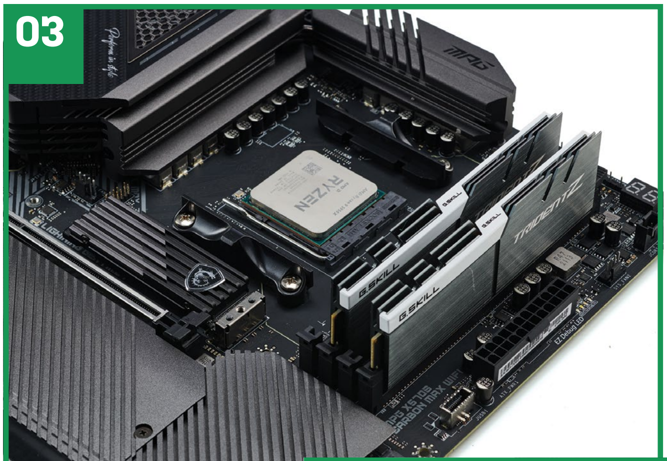
## MSI SPATIUM M480 2TB M.2 SSD

*WWW.MSI.COM*

You might recognize this bad boy from our MSI-themed build in the last issue. It's a fierce competitor despite MSI being a newcomer to the SSD market, a move no doubt inspired by the need for next-gen console gamers to upgrade their drives. With full PCIe 4.0 support on our CPU and mobo, we're expecting top performance from this SSD. • *RRP $360 • Street price: $270*

## Total $3,560 (street price $3,820)

# THE 4K BUILD STEPS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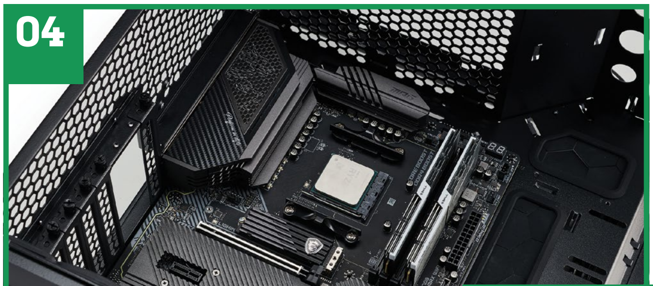
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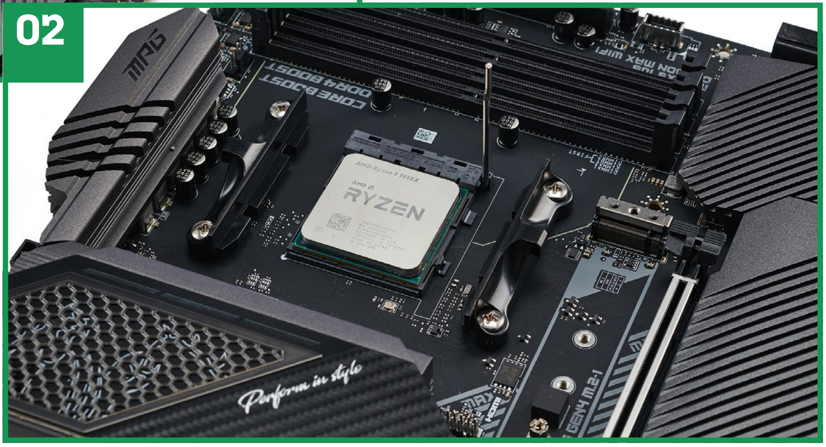

02

01

### Torrential Downpour

You got it, we're doing another case stripdown. This one's a bit more involved; you need to remove all the panels, starting with the glass sides, which remove easily with push-pins. From there, you'll also need to yank off the front panel, remove the dust filter behind it, then unscrew the roof panel from the rear and slide it off. Since we're installing a big AIO cooler in the front of the case, you'll have to unscrew the Torrent's front two fans along with the black cover plates above and beneath them. Be careful when doing this; these big fans are liable to fall into the case when you extract the final screw.

02

### Ryzen to the Occasion

You might expect AMD's current top-end processor to be different from the 5600X, but nope, we've got another super-easy Ryzen chip to install. You know the drill; lift that retention arm, drop the processor into the socket with the gold triangle lined up, and lower the arm back into place. Unlike our 1080p build, you'll want to leave the plastic bracket around the CPU socket in place, since we'll need it to install our cooler later. If your motherboard didn't come with this bracket and backplate pre-installed, check the box.

03

### Stylish Sink

Slot the memory into the priority DIMM ports and push until it clicks at both ends and the clasps on each slot snap shut. Once it's in place, we move on to our SSD. The Spatium M480 comes with an integrated heat sink that is hard to remove, so we won't be using the motherboard's own heat shield. Remove the slim shield closest to the CPU socket (marked 'Lightning Gen4 M.2') and move the silver M.2 standoff one hole closer to the M.2 slot. Insert the drive and push it down to align it with the standoff, then secure with the tiny M.2 screw. Our mobo and drive are both from MSI, so they actually match perfectly.

04

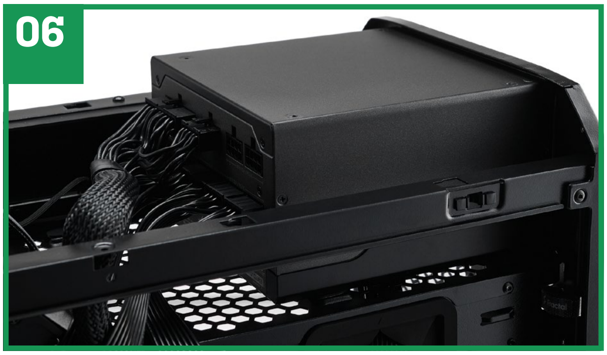
### Mothership Connection

Let's install our motherboard. No messing around with standoffs needed here; just lower the board into the case and line up the rear I/O with the slot, making sure the central mounting peg fits in the matching hole. Secure with the included screws, and as always, be careful not to over-tighten these as you may risk damaging the PCB. This X570 motherboard is fairly heavy with its masses of heat spreaders, so handle it carefully as you install it. You may also want to tuck away the cables from the fans pre-installed in the base of the case so you don't accidentally trap any of them beneath the board.

05

### Bracket Racket

Installing the radiator of our Lumen cooler inside the Torrent can be a bit tricky. You'll need the case's separate fan brackets, which come in a small extra box handily labeled 'Torrent Fan Brackets'. These brackets



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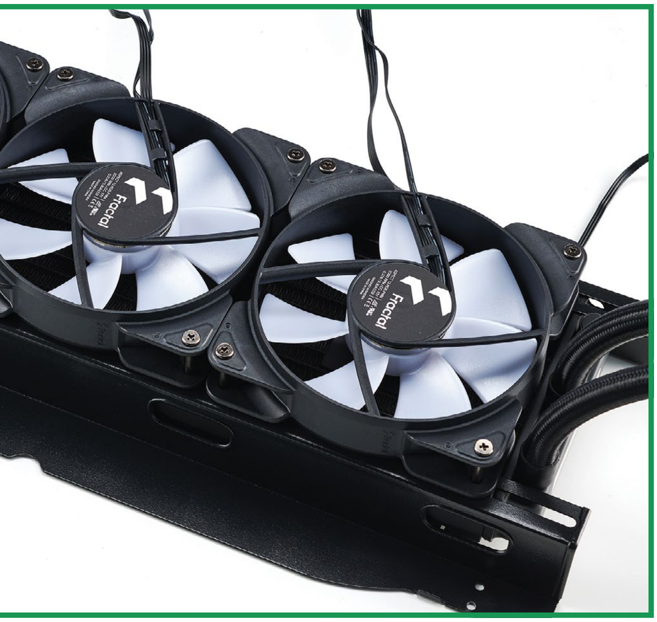
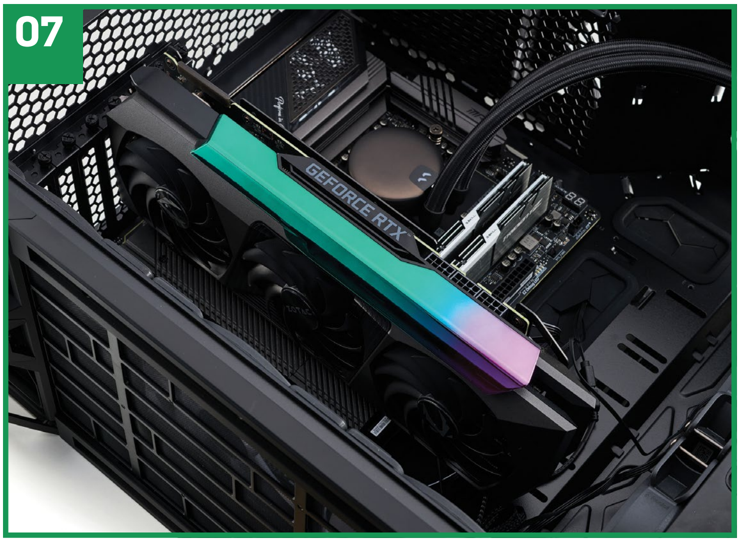




07

need to be installed between the fans and the radiator, using the long screws included with the cooler, with the fans on the inward side of the radiator (the same side as the coolant tubes). The fans should face into the radiator itself, so they suck air into the case when it's mounted. With the bracket fitted, mount the radiator at the front of the case and screw it in using the same screws that secured the plates surrounding the original case fans. Fit the AMD bracket and clips to the pump block and clip it on over the CPU, tightening above and below with the spring-mounted screws.

## 06

### Confounding Cables

There's a shock twist! We're going to install the PSU before the GPU this time around, to make things easier for cable management. The power supply mounts cleverly in the roof of the Torrent case, so attach your cables (ATX, CPU, two PCIe cables, and one accessory cable) and then slide the PSU into the space at the top. Screw it into the case, then proceed to cable management, leaving the PCIe cables loose for now. You'll want to daisy-chain the power and RGB cables from the masses of fans where possible to minimize your header use; the power cables can be plugged into the fan hub behind the motherboard, which itself should then be plugged into the sys_fan1 header on the board. Use the JRainbow1 header for the daisy-chained RGB cables.

## 07

### Big GPU, Big Price

The final component we'll be installing in this feature is the ludicrously expensive RTX 3090, our monster GPU. There's not much to say here; remove the case's blanking plates and then insert the card into the PCIe socket, ensuring the clasp snaps shut before screwing the card in at the rear I/O. You may notice that there's some sag in the GPU (and in the 3070 Ti found in the 1440p build) but this isn't a huge concern and it won't impact performance. It's vital to remember, though, that these hefty GPUs need to be robustly packaged inside the case if you plan on transporting the completed build since they're not as well-secured as more lightweight graphics cards. Don't forget to plug in those final power cables once the GPU is in place.

## 08

### Shutting Down

And with that, our final build is complete. Return all those panels to the case—don't forget the dust filter behind the vented front panel—and screw the top panel back into place. Mission accomplished; now all that's left is to hop into the BIOS to enable XMP and check our fan curves are all up to scratch. The X570 and B550 motherboards we've used may require a BIOS update before they will support 5000-series Ryzen processors; we did this using a Ryzen 5 3600X, but any pre-5000 Ryzen chip should do. Time to install Windows, download some games, and start benchmarking!

# TEST DUMMIES

**IT'S US;** we're the test dummies. Except we're not dummies, because all three of these builds booted on first attempt. Big pat on the back for us, round of applause, bullhorns, etc. We're pretty happy with how the build process went, barring the mechanical difficulty of installing the necessary brackets on the Fractal Design cooler in the 4K system. No significant hiccups to discuss here, though.

Before we get into the nitty-gritty details of our test results, let's break down the decision-making process behind our next selection of benchmarks. You'll be seeing these tests a lot in the coming issues of *Maximum PC*, so we felt it best to address why we chose the benchmarks we chose.

First up, we're keeping two bits of software from our old benchmark tables: CrystalDisk and 3DMark FireStrike. CrystalDisk needs no real introduction; it's a super-reliable drive speed test, which gives us real-world figures for easy comparison. We're still using version 5.2 of the program, which we've found to be reliable and avoids the feature bloat of later iterations. With FireStrike (and its 1440p and 4K variants, Extreme and Ultra), we opted to keep it since it's an extremely common choice of graphics and physics test, and the base test is available for free in the trial version of 3DMark.

On to the new stuff. Cinebench remains the best option for straightforward CPU testing, so we've upgraded to the most recent version (Cinebench R23) and will be testing both single-core and multi-core performance going forward, for greater clarity. R23 does take longer to bench than R20 since it fills a ten-minute slot with as many passes as it can, but that's a fair trade-off for greater test accuracy.

With games, we've expanded our selection to include some new game benchmarks. *Total War: Three Kingdoms* replaces *Total War: Warhammer II* as our CPU-bound strategy title, perfect for measuring combined CPU and GPU performance. Elsewhere, we've got *Metro Exodus* and *Cyberpunk 2077*, the latter of which has a particularly brutal RTX benchmark that incorporates ray-traced reflections, shadows, and general lighting effects. We've tested both RTX and regular graphical settings here for both of these games, to demonstrate the practical impact using ray-tracing will have on your gaming experience.

All of these games were tested at the 'Ultra' graphical preset (although it should be noted that *Metro Exodus* features a GPU-hammering 'Extreme' option too) at native resolutions, with the appropriate version of 3DMark FireStrike used for each build. Crucially, we're not using Nvidia's DLSS or AMD's FSR options; these are base performance results, and using these resolution-scaling options is almost guaranteed to result in better performance but also greater variation between GPU models. We're using AMP/XMP memory profiles for full RAM speed, but no manual CPU overclocking.

### Benchmarking Results

Although we took the time to cross-reference our results with other users' findings online, we weren't especially surprised by any of the figures we got here. Looking at the 1080p build first, we were pleased to see that the RX 6600 XT performed well at FHD resolution, nailing 60+fps in all of our non-ray-traced game tests and scoring highly in 3DMark FireStrike.

Turning on RTX settings did reveal that the 6600 XT isn't well-suited to ray-traced tasks, though. A significant hit took our framerate below 60fps in *Metro Exodus*, while the legendarily demanding *Cyberpunk* Ultra RTX benchmark came back with an unplayable eighteen frames per second. The Ryzen 5 5600X did well in *Total War: Three Kingdoms* and returned a solid single-core score in Cinebench R23 but, unsurprisingly, lagged far behind the other two builds in multi-core performance.

SSD performance placed our 1080p build pretty far beneath the 1440p and 4K machines too, with the ADATA Legend 840 not hitting its advertized speeds (but still managing a respectable 3.3GB/s read and 2.4GB/s write in CrystalDisk). Meanwhile, the other machines sit close to the peak of M.2 Gen4 capabilities, with the Samsung 980 Pro lagging a little in write speeds while the MSI Spatium M480 drive actually exceeded its advertized speed of 7GB/s by a small amount, which was impressive.

In our 1440p rig, we saw solid performance across the board at our target resolution, with notably excellent single-core performance in Cinebench R23 from the Intel i7-12700K; most likely thanks to that CPU's new performance/efficiency core architecture. Accordingly, this build also excelled in *Total War*. Ray-tracing in games still caused a major performance dip, although, in practical terms, this could be mitigated by the use of DLSS.

**1080P, 1440P & 4K BENCHMARKS**

| | 1080p build | 1440p build | 4K build |
|---|---|---|---|
| **Cinebench R23 Single-Core** (Index) | 1,537 | 1,931 | 1,691 |
| **Cinebench R23 Multi-Core** (Index) | 10,632 | 22,111 | 28,692 |
| **CrystalDisk QD32 Sequential Read** (MB/s) | 3,287 | 6,674 | 7,089 |
| **CrystalDisk QD32 Sequential Write** (MB/s) | 2,419 | 4,920 | 6,743 |
| **3DMark Fire Strike** (Index) | 24,814 | N/A | N/A |
| **3DMark Fire Strike Extreme** (Index) | N/A | 17,991 | N/A |
| **3DMark Fire Strike Ultra** (Index) | N/A | N/A | 12,785 |
| **Cyberpunk 2077** (fps) | 68 | 64 | 48 |
| **Cyberpunk 2077 RTX** (fps) | 18 | 24 | 23 |
| **Metro Exodus** (fps) | 75 | 74 | 77 |
| **Metro Exodus RTX** (fps) | 52 | 53 | 52 |
| **Total War: Three Kingdoms** (fps) | 72 | 78 | 61 |

All games tested at 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

Finally, the ultra machine did well, although struggled noticeably more with games at 4K. *Cyberpunk 2077* is renowned for battering graphics cards at higher resolutions, which was fairly demonstrated by these results, although the RTX 3090 handled 4K ray-tracing a little better than the RX 6600 XT did at 1080p. The Ryzen 9 5950X also didn't quite measure up as well as we'd hoped, with single-core performance that fell behind the cheaper i7-12700K and lower framerates in the *Total War* benchmark compared to other games.

### Closing Remarks

Our work here is done; we now have a shiny new set of benchmark results to compare all our future builds against. We'll also be using the relevant set of scores for PC and laptop reviews going forward, although you'll probably notice that those figures aren't present in our reviews section this issue—time constraints and different review writers made this impossible.

Building and shooting three PCs for one feature was certainly a challenge, and not one we'll be repeating anytime soon. But with our updated benchmarks, we're hopeful that we'll be able to provide a good reference point for our future builds for at least the next year or two. But before long, they'll need updating again, and we'll be ready to rise to the challenge.

## BENCHMARK BOUNTY

**In the world of system benchmarking, there are literally hundreds of possible options for testing your machine. Even just game testing provides a vast selection of possible tests; more and more games ship with a built-in benchmark (or add one post-release, as CD Projekt Red did for *Cyberpunk 2077* following user demand).**

**There is also always the option of using a framerate tracker—which is easier than ever now that Radeon and GeForce software includes it as standard—and simply playing a game to get an average framerate rather than running a benchmark test. This can serve to provide a better 'real world' framerate, but there are several potential pitfalls here; this method is sure to provide greater performance variation (particularly in online games), which is an issue for comparing framerates between systems.**

**There were some popular non-game benchmarks that we considered for our new tables but, ultimately, they didn't make the cut. The first of these was PCMark 10, which bills itself as 'the complete benchmark for the modern office'. Since a lot of our builds are gaming-focused powerhouses, we felt that it wouldn't be the most useful reference point. It's also from ULBenchmarks, the producers of 3DMark, and we wanted to avoid including multiple tests from the same creator.**

**Geekbench is another common test for CPU performance, frequently used since it offers compatibility with ChromeOS, Mac, and Android systems as well as Windows. We opted not to use this due to PCs being our main focus, although you may still see us reference it in some reviews (such as the Chrome tablet review in this issue!)**

**Lastly, SiSoft Sandra is a highly versatile tool for benchmarking every part of your PC, including some excellent memory performance tests. We decided that it was a bit specialized to use for general benchmarking purposes, although we've used it in the past for specific component analysis and may do so again in the future. If there are any benchmarks we haven't discussed, but you think are relevant in today's hardware-testing landscape, drop us an email to let us know!**

# RYZEN AGAIN

# THE RESURRECTION OF AMD

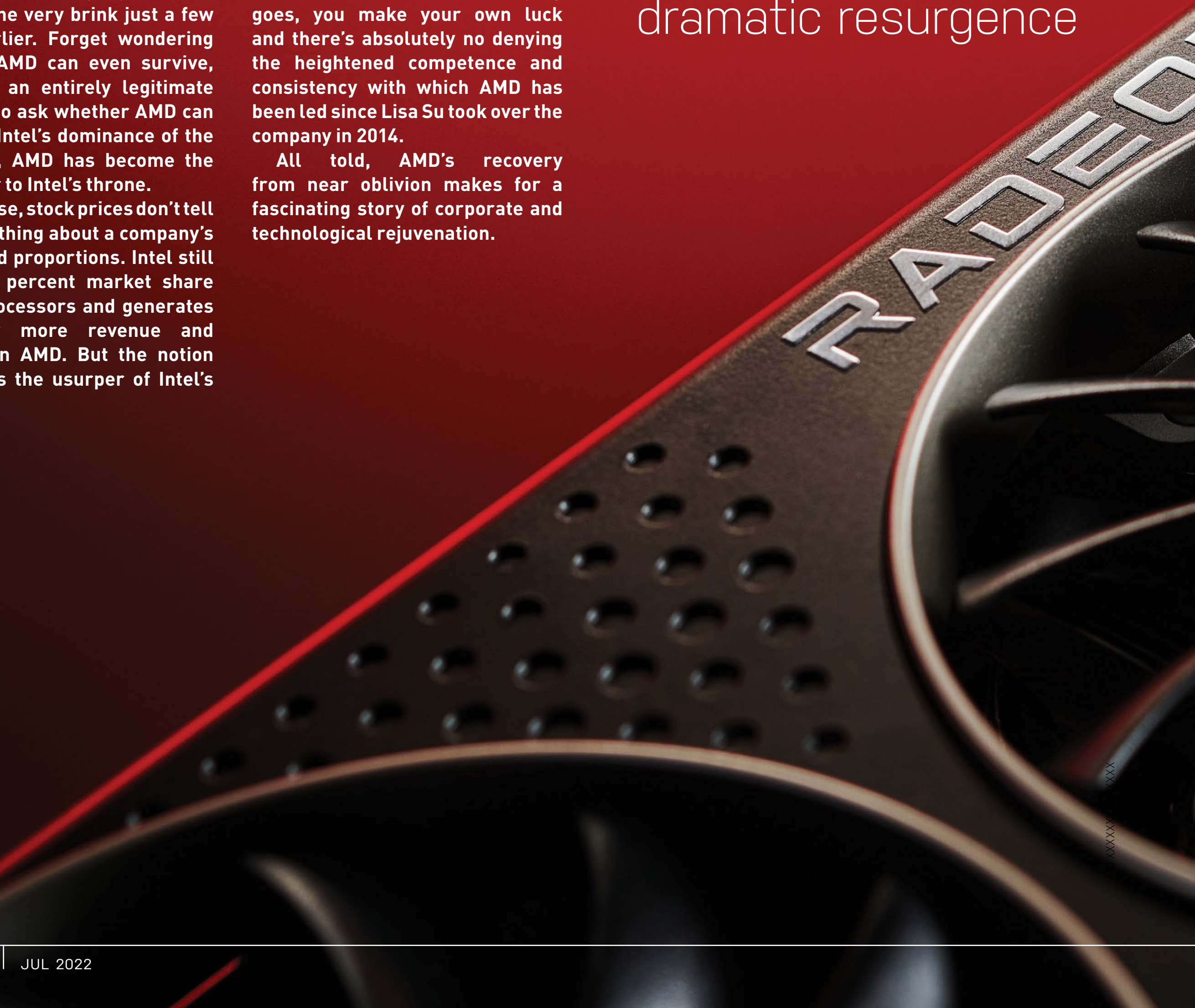
Five years ago, AMD nearly went to the wall. Now, it has the edge on Intel and Nvidia, and billions in the bank. *Jeremy Laird* investigates its dramatic resurgence

**MAKE A NOTE** of the date, 22nd February 2022. That was the day AMD's market capitalization—essentially, its overall value as a company—surpassed Intel's for the first time. It was nothing less than a spectacular reversal in fortunes for a company that had been on the very brink just a few years earlier. Forget wondering whether AMD can even survive, it is now an entirely legitimate question to ask whether AMD can overturn Intel's dominance of the PC. Truly, AMD has become the pretender to Intel's throne.

Of course, stock prices don't tell you everything about a company's real-world proportions. Intel still has a 75 percent market share for PC processors and generates massively more revenue and profit than AMD. But the notion of AMD as the usurper of Intel's position as the predominant purveyor of PC processors and platform technology is now more plausible than ever.

How, exactly, did AMD turn it around? Now that's a question. As we'll see, a little bit of luck didn't hurt. But as the saying goes, you make your own luck and there's absolutely no denying the heightened competence and consistency with which AMD has been led since Lisa Su took over the company in 2014.

All told, AMD's recovery from near oblivion makes for a fascinating story of corporate and technological rejuvenation.



AMD Ryzen 9 5950X
AMD
RYZEN

**UNDENIABLY INTIMATE**. Often symbiotic. And occasionally parasitic. Such has been AMD's relationship over the decades with its greatest rival, Intel. Truly these are two companies with a shared destiny. The story of AMD begins way back in 1969. Inevitably, Intel looms large right from the start. AMD was founded by eight former employees of Fairchild Semiconductor and headed up by none other than Jerry Sanders, former marketing boss of Fairchild and the leading figure in AMD's early years. It was only 12 months earlier that Robert Noyce and Gordon Moore also left Fairchild to set up... you guessed it, Intel.

Both companies set out to make an impact in the nascent integrated circuits business, otherwise known as computer chips. But from the start, they took different paths. Intel went heavy on the R&D to create its own designs, while AMD opted for the quicker and less expensive route to market by being a so-called second source supplier of microchips designed by Fairchild and National Semiconductor.

Second sourcing is all about securing reliable component supply and not depending on just one company. You can read how AMD went from a second source supplier of IBM-compatible CPUs to sharing full access to Intel's all-important x86 instruction set in the boxout on page 37. But suffice to say, by the early 1980s, AMD was carving out a niche as the leading alternative to Intel in the PC processor market.

Intriguingly, AMD was much more competitive during this early period than the standard narrative of perennial underdog allows. The usual refrain around AMD's latter-day success with its current Zen-based CPUs involves the mighty K8 series, the architecture that underpinned the Athlon 64, as the only substantial example of AMD getting one over on its arch-nemesis. But the real story is much more complicated than that.

**AMD's Zen 3 architecture is keeping Intel's latest Alder Lake CPUs honest.**

As early as 1984, AMD was manufacturing Intel's 286 processor as a second source supplier to IBM but achieving up to 20MHz clockspeeds whereas Intel's in-house chip topped out at 10MHz. The 386 era was something of a hiatus as AMD and Intel feuded over rights to the x86 ISA, but when AMD eventually managed to reverse engineer the Intel chip, just like the 286, AMD's take on 386 outclocked its Intel rival.

It wasn't until the Pentium era in the mid-1990s, however, that AMD attempted its own true in-house design, the ill-fated K5. Arguably AMD's first major failure, K5 arrived later than planned in 1996, missed its clockspeed targets, and generally couldn't compete with Intel's then protagonist, the Pentium Pro. AMD recovered with the K6 the following year and kept Intel honest right through until late 2003, often landing significant blows with chips like the K7, otherwise known as the first Athlon processor, but never quite knocking Chipzilla out. That brings us to a pivotal moment in AMD's history, the arrival of K8, the mighty Athlon 64.

Codenamed Clawhammer, the Athlon 64 was the first desktop CPU to deliver 64-bit instruction capability to the desktop. Not only that, but it also delivered outstanding per-clock performance at a time when Intel's Pentium 4 Netburst architecture was hitting a frequency wall. Once intended to scale all the way to 10GHz, Intel found clockspeed gains increasingly tough beyond 4GHz. The Athlon 64 wasn't just competitive, it absolutely trounced the Pentium 4.

**Due later this year, Zen 4 will pack 5nm technology and a massive 40 percent increase in single-core performance.**

K8 was killer in server systems, too, thanks to its advanced integrated memory controller and HyperTransport interlink, which made Intel's Front Side Bus and northbridge technology look every bit as antiquated as it was. K8 should have been the moment when AMD finally became Intel's equal. But, somehow, AMD let that advantage slip. As the years ticked by and K8 and its descendants aged, AMD's product execution got worse and worse. Not only did AMD fail to release a truly new core architecture for eight years following the original K8 but when it did make a major revision, taking K8 quad-core and calling it K10, AMD managed to add a serious flaw, known as the 'TLB bug'.

From there, the K8 line never truly recovered. By the late 2000s, something radical and new was required. That something turned out to be Bulldozer. Intended to be the once and future king of CPUs, Bulldozer instead became the villain of the AMD story, the architecture that nearly brought the company down. Released in late 2011, Bulldozer was by many measures the most advanced and forward-thinking PC processor AMD, or any other company for that matter, has ever produced. It unceremoniously ditched conventional thinking around CPUs containing multiple almost entirely discrete CPU cores in favor of a much more complex and highly integrated architecture designed around modules.

Each module contained a pair of integer units and shared not only its instruction decode and retire hardware but also L1 and L2 cache along with a single floating-point unit. Unlike anything AMD and Intel had produced before, the thinking behind Bulldozer was to produce smaller, more efficient chips that would deliver exceptional multi-threaded performance for a given die area.

## BULLDOZER ISSUES

Marketed as the AMD FX, part of the problem with Bulldozer was that it didn't contain conventional cores that could easily be compared with Intel's CPU or even AMD's legacy designs. The first top-of-the-range FX 8150 chips packed four Bulldozer modules, but AMD chose to pitch them as eight-core CPUs. While a Bulldozer module was clearly more complex than an Intel CPU core, such were the extensive shared resources in each dual-

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integer module that single-core performance was disappointing despite running far higher 4.2GHz peak clockspeeds compared to its predecessor, and indeed, Intel's 3.8GHz Core i7-2600K competitor.

And when we say disappointing, we mean it. Not only was Bulldozer slightly slower than AMD's elderly and outgoing Phenom II K10-based CPUs when it came to single-core workloads, but Intel's 2600K was also roughly 50 percent faster. Compounding the single-core performance problem was the fact that the PC software ecosystem had yet to fully embrace the multi-threaded model, something that was particularly true of games, not least because the prevailing iteration of Microsoft's DirectX multimedia API had poor support for multi-core CPUs.

The upshot? Bulldozer had limited opportunity to do its multi-core thing. But even when it could, it was more a case of closing the gap to the merely quad-core 2600K than actually overtaking it. Bulldozer definitely did not perform like a full eight-core CPU and it was, by any sane measure, a failure. The consequence for AMD's business was catastrophic. In 2012, AMD lost over $1billion. By mid-2015, most industry observers were predicting AMD would go bankrupt. In total, it took five long years for AMD to return to profit.

The story of how AMD turned things around from the Bulldozer debacle obviously centers on Zen, the CPU architecture that saved the company. But there's plenty more to AMD's revival besides. Indeed, some aspects of AMD's recovery date back to long before Bulldozer appeared, let alone Zen. In 2008, AMD announced plans to spin off its in-house foundry, the part of the company that fabricated CPU dies, into a new, separate entity known as Global Foundries.

At the time, the move looked like a desperate measure to inject funds into an increasingly cash-starved business than a positive long-term strategy. However, the latter is exactly how things have now turned out. When AMD ditched its own fabs, Intel had long been the undisputed world leader in chip production. More recently, Intel's fabs have been in serious trouble. Its 10nm node has taken so long to come up, that Intel felt the need to rebrand it 'Intel 7' to make it look more competitive. Intel 10nm was at least five years late when it came fully on stream last year.

All the while, AMD has been a customer of TSMC, the Taiwanese foundry that now has a clear edge over everyone else when it comes to process technology. Such is TSMC's current technological advantage, Intel has made the humiliating move of announcing plans to farm out some of its own chip production to the Taiwanese outfit. Admittedly, TSMC's 7nm node is probably only comparable to Intel's 10nm node in terms of transistor density and efficiency. But AMD was able to

**AMD's Ryzen mobile CPUs are even more competitive than its desktop chips.**

© AMD

**AMD's RDNA 2 cards pack a punch, but RDNA 3 will be the next big leap forward when it arrives later this year.**

start producing CPUs on the TSMC 7nm in mid-2019. It would take Intel another 2.5 years to launch its first 10nm desktop processor, the 12th Gen Alder Lake CPU.

## TSMC ADVANTAGE

Making matters worse for Intel, TSMC has actually been producing chips on its even more advanced 5nm node since 2020 for other customers, most notably Apple. AMD is due to launch its first 5nm CPU later this year. We don't expect Intel to release TSMC's-produced CPUs until at least 2023 and it's likewise doubtful whether we'll see chips based on Intel 4, the direct competitor to TSMC 5nm, before the end of next year, either. In short, it turns out that selling off its fabs and partnering with TSMC has given AMD a huge advantage in terms of production technology. Maybe that was planned. Maybe it was luck. But it's been absolutely critical all the same.

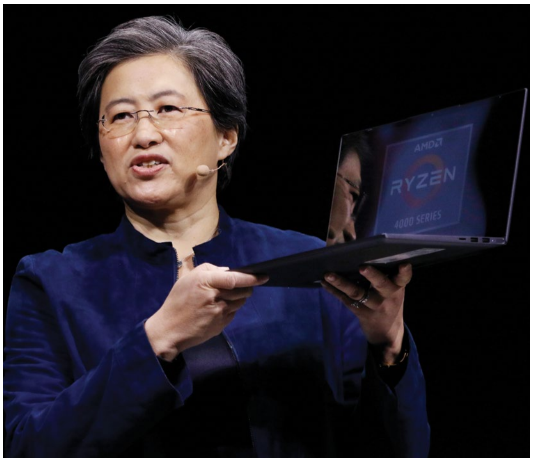
Another part of the current recovery that actually began before the Bulldozer debacle involves graphics. Back in 2006, AMD snagged Canadian graphics outfit ATI. At the time, the deal looked dubious, not least because AMD paid a cool $5.6 billion in cash and shares for ATI, or around half of what AMD itself was worth at the time. Not only was the acquisition a real stretch financially, just 18 months later, AMD had written down nearly $3 billion of that investment in ATI, which was over half of its value gone. It looked like a disaster.

If those early ATI numbers were a fiscal car crash, the long-term strategy was actually sound. Acquiring ATI put AMD in the unique position of being able to offer both high-performance processors and cutting-edge graphics. Intel's graphics capabilities were limited at the time and even now it has yet to prove the new Arc project will amount to truly competitive GPUs. Meanwhile, not only has Nvidia lacked an x86 CPU product of any kind, it lacks the licensing required to even contemplate competing in that market.

As it happens, one of the most obvious direct benefits to AMD of that CPU-GPU nexus enabled by ATI involves not the PC, but consoles. Thanks to AMD's unique ability to offer its customers both processing and graphics, in 2013 not only the Microsoft Xbox One but also Sony's PlayStation 4 were launched with AMD power. Admittedly, per-unit revenues for AMD from consoles at the time were thought to be puny. However, with millions of consoles sold AMD was pulling in vital cash. By the end of 2013, AMD actually turned a profit for a quarter or two, despite its core CPU business still shrinking at the time.

Granted, AMD's losses continued to swell through 2014 and 2015. But the console deals provided a vital flow of money during its most precarious period. Those console design wins had other benefits besides the pure cashflow. First, those console APUs, which combined AMD's low-power Bobcat CPU cores with its GCN or Graphics Core Next graphics IP, proved that AMD could adapt and integrate both halves of its main businesses into a single-chip product with bespoke elements for customers. Owning the IP in both major consoles also meant that nearly every significant game was built primarily to run on AMD's GCN graphics architecture, including most triple-A PC games.

If those are background stories, the most important elements of AMD's new dawn actually fell into place remarkably soon after the



**With Ryzen, AMD has taken laptop design wins with the big boys, including Dell, HP, and Asus.**

© AMD

release of Bulldozer. As the late 2000s bled into the early 2010s and the Bulldozer era, AMD was running out of options with its existing product lines.

The foundries had been sold off, while opportunities from ATI's graphics IP had been maxed out on console and ATI's mobile graphics IP had been offloaded at arguably far too low a price to Qualcomm. Incidentally, the result of that particular fire sale was the Adreno graphics core found in so many smartphones today. Adreno is, of course, an intentional anagram of Radeon, ATI's, and then AMD's consumer graphics brand.

Whatever, there was nothing AMD could do but dig out of trouble the old-fashioned way, by building better products. But better products don't just appear. Living, breathing people make them. And that's precisely where two key figures enter the equation, Lisa Su and Jim Keller. You can read all about Lisa Su's contribution in the boxout on page 39. But the short version is that her leadership has been critical in AMD's renaissance. If AMD wouldn't have begun without Jerry Sanders, it wouldn't have survived without Lisa Su.

As for Jim Keller, without his contribution, AMD would have struggled to turn the corner, too. Keller, of course, had been at AMD before, most notably as the lead architect on the now mythical K8 or Athlon 64. Since his last posting at AMD, among myriad other things, Keller did a stint at a certain computer outfit known as Apple. Anyway, Apple is famously secretive about almost everything. But many industry observers credit Keller with key elements of Apple's A4 and A5 iPhone and iPad SoCs.

The A5 in particular laid the foundations for what has become Apple's utterly dominant position when it comes to smartphone performance and efficiency. Ironically, that technical advantage is now spilling over into full-function computers as Apple transitions its Mac systems to in-house silicon derived from that same line of iPhone and iPad chips.

So, while Keller certainly made a huge contribution to AMD's revival, it could be his work while he was with Apple that eventually poses the greatest challenge to AMD's current business model, especially if it forces the PC industry to adopt ARM technology.

If that's a story for another day, what has mattered for AMD's revival is Keller's involvement with Zen, the CPU architecture that turned AMD's fortunes around. As Keller himself says, his primary contribution isn't typically the nuts and bolts of a chip's architecture, though we suspect he's pretty knowledgeable when it comes to those elements. Instead, Keller has always emphasized his role in getting people working together effectively.

## GROWING AUTHORITY

According to an interview with Keller last year, he took the job at AMD on the proviso that he would be given broad authority for developing what was to become AMD's savior, the Zen architecture. When he arrived as CPU president at AMD in 2012, he had 500 people under him. By the time he left in 2015, that number had swelled to 2,400. As Keller quipped, with that many people under his command, he was "hardly writing RTL (the low-level abstraction that allows chipmakers to lay out the very wiring of a CPU)".

Keller says he operated under the assumption that everything about Bulldozer was bad. He wanted a clean slate and any existing technology needed to prove itself worthy of inclusion in future products. But as critical as his role clearly was, he resists the idea that he was the 'father' of Zen. In fact, Zen was designed by hundreds of engineers including an SoC team split between Texas and India, a group in Colorado was responsible for the floating-point cache, another in Texas did the core execution front end, while the architecture's broad methodology team was spread across the world.

Still, Keller's influence on Zen is undeniable and it's likely that every iteration of Zen so far, including the latest Zen 3 architecture in today's Ryzen 5000 Series chips, was laid out in at least broad terms as part of the long-term roadmap developed under Keller's

## HOW DID AMD END UP WITH TOTAL ACCESS TO INTEL'S PRECIOUS X86 ISA?

**In the early days of desktop computing, the market was awash with competing and indeed incompatible microarchitectures. But IBM was on a quest for broad software compatibility, a vision it rightly thought would accelerate the adoption of desktop PCs. So, when IBM selected Intel's 8086 architecture for its nascent PC, it also dictated a 'second source' supplier for the very same CPU. Enter AMD as that second source supplier, manufacturing direct copies of the Intel 8086 under license.**

**When Intel declined to extend that license to include the 386 successor to the 286 in the mid-1980s, AMD was forced to reverse engineer the chip. Intel sued, lost, and eventually agreed to a license that allowed AMD to build chips around Intel's x86 instruction set so long as it didn't directly copy the architecture of its CPUs.**

**If that licensing arrangement inevitably involved money in Intel's direction, all that ended abruptly in November 2009. Thanks to Intel's adoption of AMD's 64-bit extension of the x86 ISA, the original creator of x86 was no longer in a position to demand royalties from AMD and a comprehensive, royalty-free, cross-license platform was agreed upon. AMD is free to use x86, Intel is free to use x86-64 and neither pays the other party a penny.**

AMD
64
Athlon™

AMD's 64-bit extensions to the x86 ISA have put it on an equal footing with Intel.

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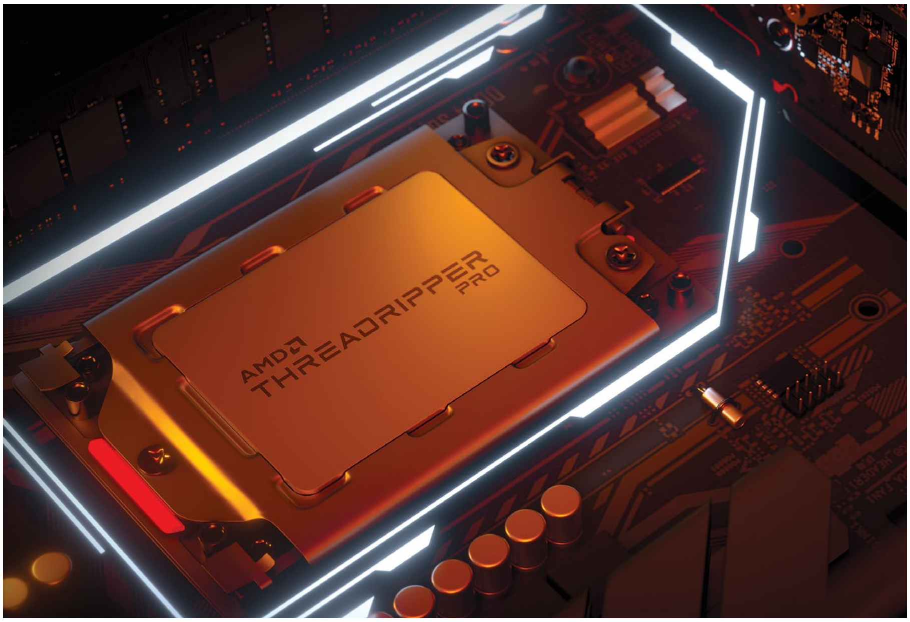

leadership. Everything we've seen so far from Zen is a Keller-era chip. All of which just leaves the minor matter of what makes Zen tick? Why has it been such a smash hit CPU design?

Revealed in February 2016 but not actually available to buy in the form of the Ryzen 1000 series CPUs until a year later, Zen was a ground-up new architecture just as Keller desired. In some ways, it was a more traditional design than Bulldozer and its highly-integrated descendants. Zen returned to discrete cores, each with its own fetch, decode, execution, and retire, plus L1 and L2 cache memory.

## PIPELINE DREAMS

In fact, the entire pipeline was redesigned with shorter, more responsive instruction pipelines for more performance per clock, thereby dumping Bulldozer's clockspeed-enabling deep pipeline design. The net result was over 50 percent improvement in performance per clock from each thread compared with Excavator, the final iteration of the Bulldozer line of CPU architectures, and something in the region of 80 percent better by that same measure over the original Bulldozer cores. Granted, it wasn't enough to beat Intel for single-threaded performance. But AMD was back in the game, quite literally given how important single-threaded performance is to gaming.

Just as important as radically improving per-core and per-clock performance with the original Zen architecture was the shift to multi-chip modules with Zen 2. Instead of producing the entire CPU on a single die, the Zen 2 processor package contains multiple so-called 'chiplets'. Zen 2's 'compute' die was built on TSMC's 7nm node and contained eight cores. That was paired with a central 'I/O' die manufactured on Global Foundries' cheaper 12nm node and connected via AMD's Infinity Fabric links.

The I/O die is a hub for all off-chip communications, housing the PCIe lanes for the processor, plus the memory controller and aforementioned Infinity Fabric links to further compute chiplets. Yep, further compute chiplets. In other words, with Zen 2 AMD could add another compute die and in an instant take the total core count up to 16, far more than Intel offered at the time for desktop customers.

That physical modularity would eventually allow AMD to introduce crazy core count chips for the high-end desktop market in the form of ThreadRipper CPUs, eventually topping out at fully 64 cores. Intel's hitherto monolithic designs do have some advantages. Chip-to-chip latency in an AMD chiplet design can create performance bottlenecks in certain scenarios.

But, crucially, Intel's monolithic approach makes it slow to respond. Where AMD can, in theory, simply insert another compute die full of cores into the CPU package, Intel must design, tape out and optimize a whole new chip if a core count increase is desired.

**AMD's chiplet technology has enabled ThreadRipper CPUs with crazy core counts.**

**AMD's CEO shows off its upcoming Intel killer, the Zen 4-based Ryzen 7000 CPU.**

## COMPREHENSIVE ROADMAP

The final part of the Zen puzzle is what you might call roadmap execution. AMD didn't just wheel out the original Zen architecture in the Ryzen 1000 series chips and then call it a day, something it was arguably guilty of with K8. Under Lisa Su's overall command, Keller and his team laid down a multi-year, multi-generation roadmap of architectures with planned improvements and upgrades. And more important than just about anything else, AMD then executed that roadmap flawlessly. No delays. No major bugs.

In 2019 came the first really big upgrade in the Ryzen 3000 series and Zen 2. Although a development of the original Zen architecture and cores, it still increased single-thread performance by a hefty 20 percent and also upped the headline core count to fully 16 cores for mainstream desktop processors, far above anything Intel was offering. Just a few years earlier, when AMD was stumbling and Intel was allowing the CPU market to stagnate, four cores were the most you could have in this same segment. AMD was radically shaking up the market.

Next, in 2020 came Zen 3 in the Ryzen 5000 series. In many ways, Zen 3 is the Zen architecture fully realized. At a high level, it looks a lot like Zen 2. You have the same chiplet architecture with 7nm compute dies, each with eight cores, plus that 12nm I/O chiplet.

But every segment of the core has been redesigned, with major changes including wider INT/FP dispatch, larger buffers and execution windows, better branch prediction, and more. In total, AMD claims a further uptick in single-thread performance for Zen 3 of 19 percent compared to Zen 2.

But arguably the most important revision was to the layout of the eight-core compute die. Previous Zen CPUs had been composed of core complexes or CCXs containing four cores. Within a CCX, each core has its own L1 and L2 cache, while L3 cache is shared across the four

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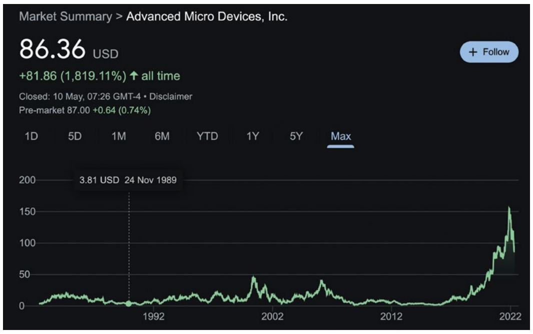
cores. Of course, Zen CPUs contain more than four cores. The problem came when a core in a separate CCX needed access to data stored in the L3 cache of another CCX. That created cache latency and impacted performance.

For Zen 3, the CCX size has been increased to eight cores. So, any Zen 3 chip with up to eight cores entirely avoids that occasionally debilitating CCX-to-CCX L3 cache latency. That's particularly important for applications like gaming that are acutely sensitive to cache performance. Workloads that more neatly lend themselves to parallelization, such as video encoding, aren't nearly as sensitive to cache latency. So, performance was already scaling very nicely with AMD's earlier quad-core CCX designs and indeed multi-chip CPU models.



**AMD's stock price has fallen from its peak, but is still 2,000 percent up from when Lisa Su joined in 2014.**

Did we mention that as these desktop chips were rolling out, AMD was also making serious headway into the laptop market for the first time? If anything, AMD's Ryzen APUs have been even more competitive. Partly that has been down to superior process technology from TSMC that is even more critical for mobile chips than desktop processors.

That advantage arguably reached its zenith in 2020 when AMD launched the 7nm Renoir Ryzen 4000 APUs for laptops. Thanks to the inherent efficiency of the Zen architecture, plus the superiority of TSMC's 7nm node and the integration of AMD's Radeon graphics technology, all the while Intel was struggling to bring its 10nm node online, AMD found itself with a killer mobile offering to which Intel had absolutely no answer.

Renoir and its 2021 Cezanne successor are so much better than the Intel alternatives when it comes to both power consumption and performance, it allowed AMD to finally break into laptops in a big way. Mobile platforms have always been a tough nut to crack for AMD thanks to Intel's greater resources and ability to help PC makers

## NEAR BANKRUPTCY TO BILLIONS
## THE LISA SU STORY

On 8th October 2014, when Lisa Su assumed leadership of AMD as CEO, the company's stock price was running at $3.25. Just over six years later, on 29th November 2021, AMD's stock hit $164. That's an increase of 4,946 percent.

So, who is the woman behind AMD's revival? Born in 1969, Su came to the US from Taiwan aged just three. As a young girl, her statistician father and accountant mother schooled her in the way of numbers. By 10 years old, her engineering instincts had her rebuilding remote control cars and it seemed her destiny to enroll, as she did, at the Massachusetts Institute of Technology (MIT) in the fall of 1986 to study electrical engineering.

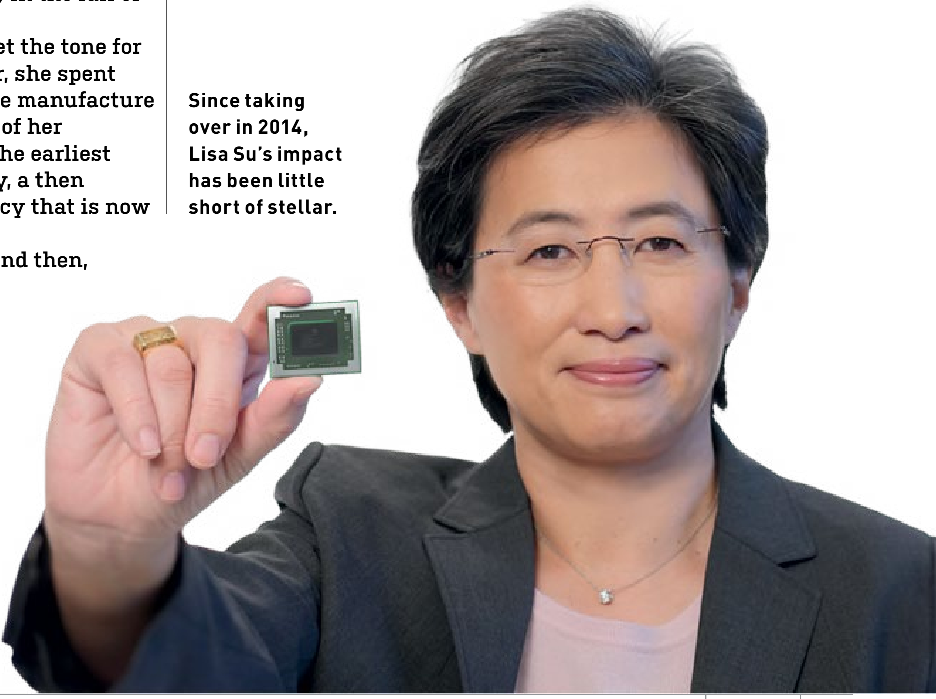
From the very start, those student days set the tone for her future role at AMD. In her freshman year, she spent time as a research assistant helping with the manufacture of test silicon wafers for grad students. Part of her doctorate research at MIT involved some of the earliest work on silicon-on-insulator (SOI) technology, a then unproven method of improving chip efficiency that is now industry standard.

Out of MIT, Su joined Texas Instruments and then, shortly afterward, moved to IBM, where she pioneered the replacement of aluminum connectors with copper, resulting in chips that were 20 percent faster. In 2000, Su was given a year-long assignment as technical assistant to IBM CEO Lou Gerstner before being appointed head and founder of IBM's Emerging Products division.

During that period, Sony CEO Ken Kutaragi commissioned Su's group at IBM with a collaboration charged with "improving the performance of game machine processors by a factor of 1,000." The result was the ground-breaking nine-processor chip that became the Cell CPU in the Sony PlayStation 3.

By 2007, Su had moved on to become CTO of Freescale heading up R&D and helping the company to float on the stock market in 2011. But it was in 2012 that she finally joined AMD as general manager, her early work included a key role in collaborating with Microsoft and Sony on console chips. It was only two and a half years later that Su was appointed CEO of AMD and the rest, as they say, is history. Or rather very much an ongoing success story.

**Since taking over in 2014, Lisa Su's impact has been little short of stellar.**



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# SHOW ME THE MONEY
## JUST HOW BAD DID IT GET FOR AMD?

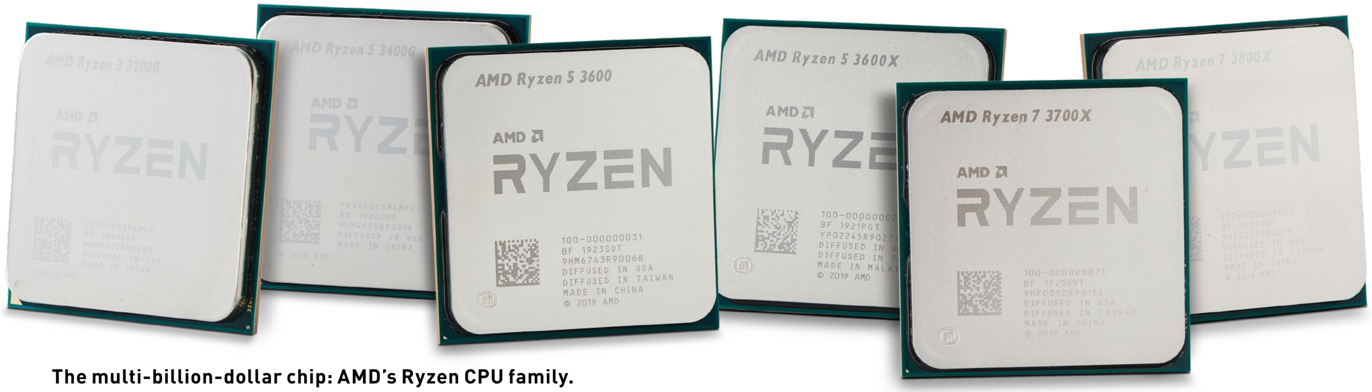
It's well known that AMD struggled in the mid-2010s. But just how bad did the cash crisis get? As the 2000s came to a close, AMD's business was turning sour. Profits of $360 million in 2010 and $491 million in 2011 flipped into a monumental loss of $1.18 billion in 2012.

In 2013, the bleeding subsided somewhat with a loss of $83 million, only for the losses to balloon once again to $403 million in 2014, $660 million in 2015, and $497 million in 2016. That's a total of $2.8 billion leaving the building over the course of six years. As for how close AMD came to folding, its cash balance of $1.9 billion at the end of 2011 had shrunk to just $716 million by mid-2016.

Clearly, that could not continue, which is why many industry analysts were predicting AMD would be bankrupt by 2020. Happily, that never happened and, by the end of 2017, AMD had begun to turn the ship with a small but symbolically important profit of $43 million. In 2018, AMD had stopped the rot, returning $337 million. A steady, if unspectacular, result of $341 followed in 2019.

But it was 2020 that proved AMD had truly entered a new era of high profitability, clocking up $2.49 billion of net income. The following year was even better at $3.62 billion, with 2022 looking set to be even stronger, with a $786 million profit in the first quarter, up a massive 42 percent on the same period in 2021.

If AMD carries on like that, it will breach the $5 billion profit barrier in 2022. And memories of the flirtation with bankruptcy just a few years ago will have been erased.



The multi-billion-dollar chip: AMD's Ryzen CPU family.

techradar

integrate their chips into the thermal and physical constraints of a laptop. In the past, when AMD had managed to produce decent but not world-beating mobile CPUs, they made almost no impact on the market. But Renoir was so good that the biggest players in the PC market including Dell, HP, Lenovo, and Asus could no longer afford to ignore AMD. They had to build Ryzen into their laptops.

### FULL SPEED AHEAD

As if all that wasn't impressive enough, check out AMD's forward roadmap. Later this year, Zen 4 and the Ryzen 7000 series of CPUs is due. Not only will Zen 4 move to TSMC's more advanced 5nm node for the compute chiplets and 6nm for i/O, but it will also bring another big step in single-thread, per-clock performance of around 25 percent. Factor in higher clockspeeds, in part thanks to that 5nm node, and per-core performance will be up by a massive 40 percent.

At launch, we're not expecting more than 16 cores. But a 24-core mainstream desktop Zen 4 product is possible, while Zen 4 ThreadRipper Pro CPUs with a staggering 128 cores are expected.

**TSMC's advanced packaging technology could be critical to AMD's future success.**

© AMD

Further out than Zen 4, things inevitably get more speculative, at least from an outsider's perspective. Zen 5 is surely a done deal from a design perspective, but little is publicly known about its core architecture or features. But if there's something about AMD's plans we'd most like an inside take on, it's any alternatives AMD may be working on to replace ye olde x86 instruction set.

How so? Apple's M1 chips in its latest Mac computers have comprehensively proven that ARM CPUs can compete on not just efficiency, but pure performance. Now more than ever, ARM looks plausible as a replacement architecture for x86 in the PC. Back when Jim Keller was running AMD's CPU business, there were indeed plans to hedge for that precise scenario with a modular CPU platform known as Skybridge that supported both ARM and x86 cores. The ARM version of Skybridge was codenamed K12 and originally due in 2016, but never actually appeared.

Last year, AMD's CFO Devinder Kumar said the company was "ready to go" with ARM CPUs if that's what the market required. For now, there are no announced ARM-based CPUs in AMD's roadmap. But we suspect Keller's work on K12 will position AMD well should the need arise. After all, it was that effort under Keller's leadership at Apple that laid the foundations for the all-conquering Apple M1 family of SoCs. If ARM does turn out to be critical in future, it also won't hurt AMD's chances that its rival Nvidia's attempts to acquire ARM itself have now failed.

If a transition to ARM for AMD and indeed the PC as a whole is a rather speculative notion, what we can say for sure is that AMD's prospects look better now than at any time in its history. Its current CPU products are as good as or better than Intel's by almost every relevant metric. And its graphics business is nearly as competitive as Nvidia's.

What's more, AMD's roadmaps for both CPU and graphics could well deliver it a clear performance and technological advantage over both of its key rivals by the end of this year. The best CPU and the best graphics chips from one company. The king of the PC? It's looking extremely likely that, by the end of 2022, it will be AMD.

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# PCs V

Games consoles have become more like PCs, and with subscription services such as Xbox Game Pass blurring the lines between PC and console gaming, which is the better platform for gamers in 2022? Guy Cocker investigates

**NOWHERE DOES** tribalism exist to quite the same extent as in the gaming world. Whether it was Atari vs Commodore in the 1980s, Nintendo vs Sega in the 1990s, or Xbox vs PlayStation in the 2000s, generations of gamers have spent decades pledging their allegiance and going to war over their platforms of choice, whether that's in the playground or on forums like Reddit.

In the last few years, though, that rivalry has settled into more of a "can't we just all get along?" kind of vibe. That's thanks to the evolving strategies of platform holders such as Xbox and

# Vs CONSOLES: GAME ON

PlayStation, who rather than preciously guarding their crown jewels like *Halo* and *God of War* as they once did, are now happy to release them on PC, sometimes day-and-date with their lead platform. Both PlayStation and Xbox also have game streaming services that actively work with PC, meaning you don't even have to own one of their consoles anymore.

That said, games consoles have had their place recently, especially over the last couple of years where entertainment options have been more limited to the home. As a result, game playing time increased by 39 percent, driving record revenues for the industry. True, the PS5 and Xbox Series X were nearly as difficult to source as PC graphics cards over the same period, but they brought with them some fantastic games, 4K 120Hz graphics, and in the case of the PlayStation, innovative new controllers.

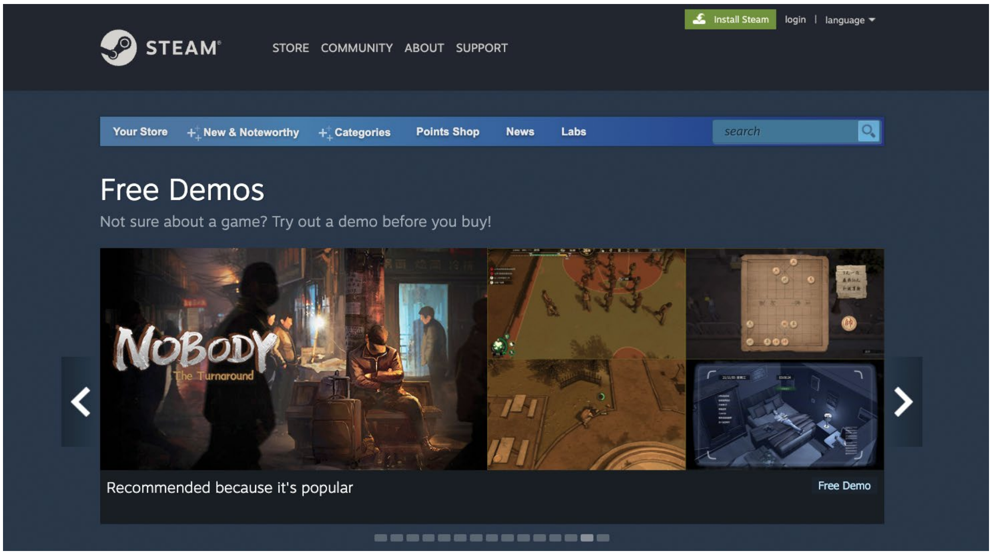
So where does this leave consoles in 2022? Is it still worth dropping $300-$500 on a dedicated games console, or is it better to spend that money on a powerful GPU to beef up your PC rig? Well, dear *Maximum PC* reader, we've put in the hard work of playing games on a variety of PCs and consoles so we can form a definitive verdict. If you're going to game, are you better off doing it on console or PC? Let's find out.

# HARDWARE

With hardware, the whole PC vs console debate at first appears to be unfair, given that you can buy a GPU such as the RTX 3090 Ti ($1,999) or RX 6950 XT ($1,099) that blows any games console out of the water when it comes to raw performance. Indeed, the RX 6800 XT ($649) and RTX 3080 ($699) both offer PS5 and Xbox Series X-beating performance on paper, although good luck finding either card for those prices at retail right now.

That's just the situation today—later this year, AMD is set to introduce its first RDNA 3-based graphics cards, which should offer a generational leap forward in performance. When that happens, you can expect performance and feature sets that leave the RDNA 2-based games consoles firmly in the dust. The same should also be true for Nvidia's Lovelace-based 4000 series cards, although if tradition is anything to go by, these will sell for much higher prices.

While the prices for dedicated GPUs are still inflated, the wild cards here for PCs are the value to be found in buying pre-built desktops and laptops. Here, you can find a 3070-based laptop (such as the Lenovo Legion 5) or a 3070 Ti-based desktop (like the HP OMEN 25L) that will trade blows with a games console for under $1000.



Free Demos

Not sure about a game? Try out a demo before you buy!

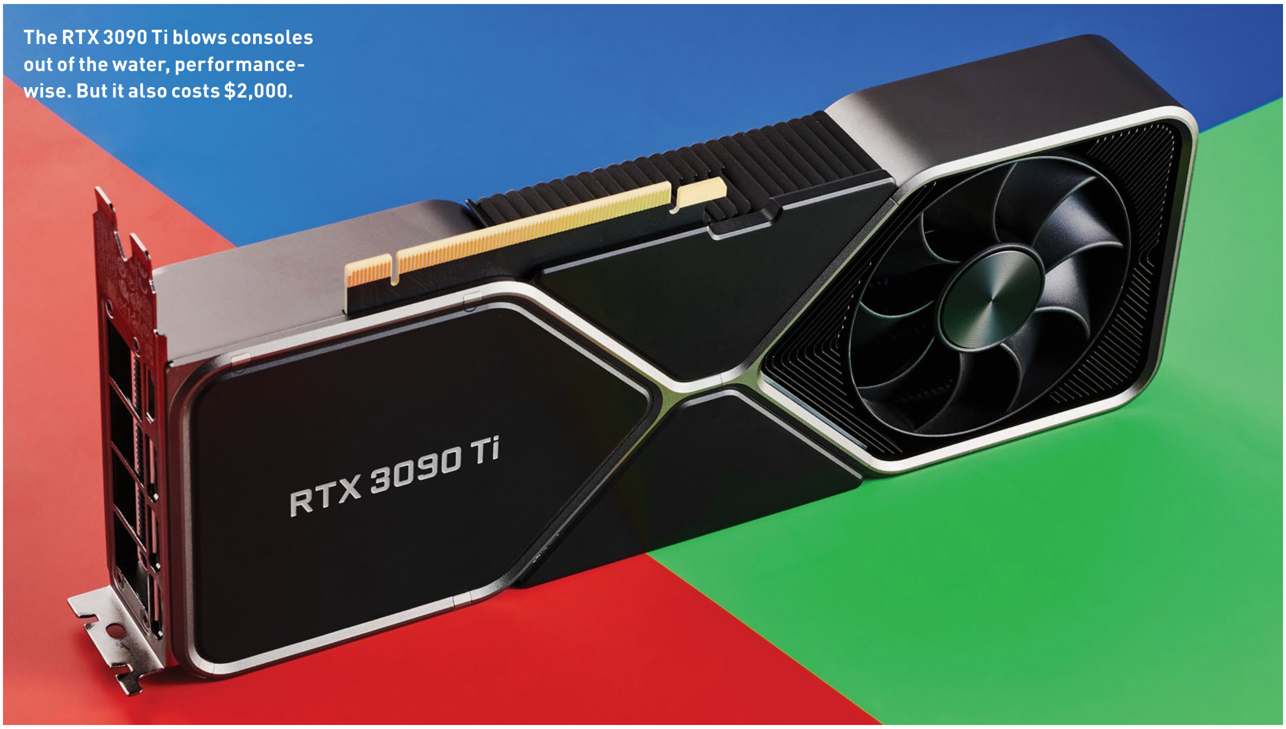
Recommended because it's popular

Free Demo

**The PC has so much free content that you could go a long time without actually spending any cash.**

That's when it becomes a more difficult choice—would you rather spend $500 on a dedicated games console, or $1000 on a PC that can do games and so much more, and in the case of a laptop is also portable?

We suspect that for anybody who uses a PC not only for gaming but also for work or creative purposes, the latter is the preferable option.



**The RTX 3090 Ti blows consoles out of the water, performance-wise. But it also costs $2,000.**

WINNER

**PCs**

**CONSOLES**

**If all you want to do is game, there's no doubt that a console is better value, at least in the short term.**

# SOFTWARE

Again, based on raw numbers, this seems like another easy win for the PC. Steam alone crossed the 50,000 game mark in 2021, with over 10,000 titles added last year alone. Compared with the 4,000-or-so PS5 and PS4 games playable on the PS5 console, there's no contest.

Of course, the vast majority of those games are, and we're being charitable here, complete and utter garbage. But this brings us to our next point—the top five games on

© STEAM

Steam at the time of writing are all free-to-play titles: *Counter-Strike: Global Offensive*, *Dota 2*, *PUBG: Battlegrounds*, *Apex Legends*, and *Lost Ark*. All great games, across a variety of genres (shooters, strategy, RPG) that could easily entertain you for the rest of the year without you having to spend a single penny. And that's without even mentioning the weekly free giveaways on Epic Games Store.

Where consoles win is on the quality of their triple-A titles. Nintendo, Xbox, and PlayStation house some of the best developers in the world, and on Metacritic's list of Top 10 Best Games of All Time, all ten are games that debuted on consoles, such as *Zelda*, *GTA*, and *Tony Hawk* games (*Disco Elysium*, which led on PC, sits just outside at number 11). Yes, most of those games came to PC eventually, but there's no denying the quality of console exclusives over the years.

However, you can't talk about games without talking about prices. Standard edition console games retail for around $60-70, and while PC games on Ubisoft Connect, Battle.net, and Epic Games Store have come close to that, you can expect to pay around $20 less for a new game on Steam, with sales and promotions offering much deeper discounts on PC post-launch.

WINNER

**PCs**

CONSOLES

**With its much larger library of games, constant free giveaways on Epic Games Store, and more console exclusives making their way over, the PC is the clear winner here.**

# CONTROLLERS & PERIPHERALS

**Xbox's Elite Wireless Controller Series 2 works on Xbox and PC.**

When it comes to controllers, PC gamers are lucky to have both a mouse and keyboard that are suited to shooters and strategy games. There are a dizzying array of options at a range of prices, with peripherals that are cordless, mechanical, and highly customizable. Wireless headsets tend to be cheaper on PC, while advanced features such as mouse mats that charge wireless mice have been common for years. Likewise, PC gamers are able to indulge whatever specialist obsession they like, from racing wheels to flight sticks, and all manner of wild and wacky VR accessories.

Consoles, on the other hand, have their own walled gardens, and a controller or a headset that works on one is unlikely to work on another. However, as sometimes can be the case, constraints have resulted in creativity, and that's particularly true when it comes to the PlayStation 5 and Switch controllers. The PS5 controller's novel rumble motors and adaptive triggers are a genuine leap forward, and while relatively few games take advantage of them, the ones that do (*Astro's Playroom* and *Ratchet & Clank*) show how far behind the PC is here. Likewise, the Switch's motion controllers make gaming easy and accessible to share with friends. It's not quite the same when you open up a gaming laptop.

Likewise, the Xbox Elite Wireless Controller Series 2 is the best traditional gaming controller out there thanks to its build quality, customization, and general responsiveness. The good news is that it also works on PC.

WINNER

PCs

**CONSOLES**

**Sony and Nintendo in particular have done a lot of work on their controllers to aid accessibility and push controller interfaces forward, demonstrating why walled gardens are sometimes a good thing.**

# DIRECTSTORAGE

Arguably the biggest technological leap forward in this generation of consoles—possibly even more so than the graphics—was the forward-looking adoption of PCIe 4.0 storage.

Still relatively rare on PCs, PCIe 4.0 drives offer incredibly fast read and write speeds that essentially double those found on the last-generation 3.0 drives.

The result is that games can load into memory extremely quickly, meaning that loading screens and those areas meant to hide loading times (think the elevators in *Mass Effect*) become a thing of the past.

The game that exemplifies the benefits of PCIe 4.0 storage is *Ratchet & Clank: Rift Apart*, where the protagonists are able to snap between different worlds at the press of a button in a way that is really quite impressive, given the detail present in those worlds.

For PCs, the problem is that while the same SSD speeds are supported on the latest motherboards, games aren't optimized to load in the same way. That should change now, thanks to the release of Microsoft's DirectStorage API in Windows 10 and Windows 11, which will allow compatible PCs to pull the same sort of tricks as the PlayStation 5.

One of the first games to support DirectStorage will be *Forspoken*, an action role-playing game from Square Enix, releasing in October. Get those 2TB drives at the ready, and if you need help choosing one, check out our SSD feature from our May 2022 issue.

msi
SPATIUM M480 | 2TB

The speed of PCIe 4.0 drives will soon be unlocked by Microsoft's DirectStorage API.

© MSI

## ONLINE/MULTIPLAYER

You have to give Microsoft credit, the company went all-in on online gaming with its Xbox Live service and, while it was the first premium online offering of its kind, it revolutionized multiplayer gaming across both console and PC. (Yes, we know Sega got there first on the Dreamcast, but Xbox Live was the real deal). It was also a canny business move—PlayStation responded with PS Plus and monthly games and Xbox replied with Game Pass, which has now delivered on the long-promised 'Netflix of games'.

Today, Xbox and PlayStation's online offerings are great from a functionality perspective, but expensive if all you want to do is play with your friends. PS Plus Essential and Xbox Live Gold are both $10 per month or $60 per year, effectively priced highly to push you towards their $15 per month PS Plus Extra and Xbox Game Pass offerings, which include hundreds of games. But do that, and fail to make savings with an annual subscription, and you're effectively paying them $540 every three years—the same as buying a new console.

Aside from certain games, such as *World of Warcraft* and other MMOs, PC gaming multiplayer is completely free. Discord has made it easy to party up with friends and maintain communication while moving between games. That said, there are a few minor annoyances. Maintaining different friends lists across platforms like Steam, Epic, and EA Origin is a faff, and it's an all-too-frequent occurrence between friends where some people will have a game on Steam and others will have it on Game Pass, and the two won't play together.

So for ease of use, it's definitely consoles, but if you don't want to bleed money just to game with friends, PC is the way to go.

**Chatting, networking and gaming with friends is enjoyably subscription-free on PC.**

WINNER

**PCs**

CONSOLES

It's not as seamless to play multiplayer on PC, but spending $60 a year on consoles is a substantial price to pay for convenience.

## GAME STREAMING

**Wait a second, isn't this supposed to be the last generation of games consoles? Neither PlayStation nor Xbox has officially said so, but analysts have speculated this could be the last era of dedicated hardware.**

**Even at the launch of the Xbox Series consoles in 2020, Xbox admitted that consoles were "already a small part of the overall gaming business". With its Xbox Game Pass service, Microsoft clearly wants you to play Xbox games wherever suits you, whether that's on a console, a PC, or streaming to your phone or tablet.**

**However, after a few false starts, that's all game streaming seems to be in 2022—an add-on service to the core experience of games processed locally on a console or PC.**

**Sony's PS Now service, which used to cost $10 a month, is now only available with the top-level $18 PS Plus Premium service to justify paying a few bucks more over the non-streaming PS Plus Extra tier.**

**Likewise, Google's ambitious Stadia service has been nerfed pretty significantly this year, with internal studios closed and projects canceled.**

**If there is a future for cloud gaming, it's probably with more casual fans who don't care so much about the premium experience you get from a local PC or console.**

Stadia has now been white labeled for use by other tech companies, such as Capcom and Bungie.

## LONGEVITY

If PC owners get four to five years out of a machine, we tend to consider that pretty good going. However, that pales in comparison to how long the last couple of console generations have lasted—there were over seven years between this current generation of Xbox/PlayStation and the previous one. What's more, games are still being released for the PlayStation 4 and Xbox One—*FIFA* and *Madden* games will probably be released for many years to come.

**PlayStation console lifespans keep getting longer: PS1's was five years, PS2's six, and PS3/PS4's seven.**

What's more, the games that came out in the dying years of a console tend to be some of the most technically accomplished, because developers have been programming for them for years and have learned to wring every last drop of performance out of them. *Ghost of Tsushima* and *The Last of Us: Part 2*, both released on the PS4 the same year the PS5 came out (2020), were stunning technical achievements that impressed so much because they were running on seven-year-old hardware.

On PC, developers have to ensure compatibility with a lot of hardware configurations, and while they do a good job of optimizing, it's just not as easy as honing for one single spec that tens of millions of players own. That said, we are constantly surprised with how well older hardware is supported. Take *God of War*—its recommended spec for 1080p 30fps is an Nvidia GTX 1060—a mid-range card released six years ago.

WINNER

PCs

**CONSOLES**

**Being able to buy a console and reasonably expect to still be playing it seven years later is an incredible deal. What's more, games just keep on getting better along the way.**

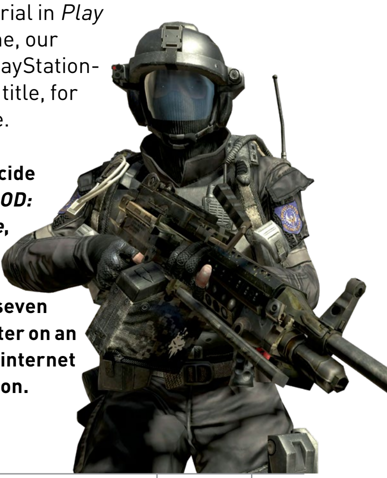
## EASE OF USE

The last decade or so has been interesting to watch, as consoles have arguably become less easy to use, while PCs are now much less technical. Before the Xbox 360, you'd pop a disc or cartridge into a console and be playing pretty much immediately; now, pop a disc in and you'll invariably have to wait for the game to install itself and download patches, if you don't also have to perform some sort of system update as well.

True, these consoles are able to do some of this in the background overnight, but only if you enable their energy-inefficient "Always On" modes. It's even worse if you buy a game digitally. *Call of Duty* and its 100GB+ install sizes take hours to download on an average connection. We picture the poor kids getting an Xbox or PlayStation for Christmas, being overwhelmed with excitement, but then having that feeling extinguished as they have to wait until Boxing Day to actually be able to play something.

The PC, meanwhile, shares a lot of those problems, but we'd argue Windows has become more user-friendly, while a lot of bugs and crashes have been eradicated. Even better, Nvidia's GeForce Experience and AMD's Adrenaline software have allowed for one-click tuning of all your games, so you don't need to worry about tweaking the settings to get a smooth framerate. Steam's Big Picture mode has also provided a viable living room interface, while Family Sharing makes it much easier to share games with your friends and family.

Ultimately though, if you want ease of use, a console is still the way to go. We've never read a command line tutorial in *Play* magazine, our sister PlayStation-focused title, for example.


**If you decide to play *COD: Warzone*, you'll still be waiting seven hours later on an average internet connection.**

WINNER

PCs

**CONSOLES**

**They're not as user-friendly as they were, but if all you want to do is play games as fast and easily as possible, consoles are still where it's at.**

© GETTY IMAGES/ISTOCKPHOTO, ACTIVISION

**If you want to make your fancy new GPU sweat, give 3DMark's Port Royal ray-tracing benchmark a try.**

## GRAPHICS

If you prefer graphics over gameplay, there's a vulgar term for you that we won't use here. But plenty of people do care about pixel counts, frame rates, and fancy effects—enough people to drive an entire industry of GPU manufacturers who are happy to sell you cards for over $1,000 that will support 4K, 240 frames per second, and graphics so real you almost feel like you're there. Games consoles can offer a whole host of effects to look like they're hitting 4K, but the truth is most of them aren't even hitting 1440p native resolution.

If you do want the prettiest graphics, there really is no other way to go but PC. Ray tracing is now on its fourth generation on the PC, and while it's still a performance killer (not even the 3090 Ti can play *Cyberpunk 2077* 4K with all ray-tracing effects turned on), it is a viable option. On Xbox Series X, the game list is limited and impacts performance on games such as *Resident Evil Village*. Then there's Nvidia's DLSS, which allows for huge performance gains at higher resolutions on PC, but which doesn't really exist on consoles.

Witness the PC port of *God of War* to see the huge performance boost available from DLSS, which looks glorious on the PC, even on a modest system. At least variable refresh rates have now hit consoles for silky smooth gameplay.

WINNER

**PCs**

**CONSOLES**

**The current-gen consoles are no slouches, but the advanced features offered by PC graphics cards leave them for dust—and that's before the next-generation GPUs arrive later this year.**

## LIVE STREAMING

**Not everyone wants to be a video star with their own YouTube or Twitch channel, but the latest generation of consoles and PCs have made it easier than ever to go live.**

**Both the Xbox Series and PlayStation 5 consoles make it easy to post gameplay online, and while you won't challenge a dedicated streamer in terms of a professional-looking stream, you can capture yourself and your game using Sony's HD Camera on PlayStation, while Xbox supports many different USB webcams, which can be a cheaper option.**

**On PC, the world is your oyster, and you can use a host of software including XSplit and OBS Studio, which we compared in the June 2022 issue, as well as a dedicated PC if you want to run things smoothly.**

**However, Nvidia and AMD have both included hardware encoders on their latest GPUs, which means you can stream with limited impact on your gaming performance. Nvidia has made great strides with AI-powered audio and video effects that can create virtual backgrounds and improve your mic audio, allowing you to have an all-in-one virtual studio.**

**AMD's RX 6000 and Nvidia's RTX series feature hardware encoders that let you stream with minimal performance hit.**

© 3DMARK

# UPGRADEABILITY

One of the benefits of closed console systems is that developers know what they're aiming for, and optimize accordingly. But often the technology can't quite keep up, so both Sony and Microsoft released upgraded "Pro" versions of the last-generation PS4 and Xbox One consoles, to take advantage of people who wanted more power.

On PC, that's not a problem, as you can just swap out an aging GPU or CPU, or add more RAM and storage as needed. You may have to change your motherboard if you're making a generational change, but it's all perfectly doable.

On consoles, the one big thing you can change is the storage, which is kind of a necessity given the small amount of storage offered by Sony and Microsoft. We have to commend Sony for allowing you to drop in your own choice of SSD, as long as it's fast enough and has a good heatsink to keep it cool.

However, as the included drive is only 825GB, an upgrade is kind of a necessity for any serious gamer. Microsoft sells its own 1TB external cards, which make expansion dead easy. However, they cost around $200 for 1TB extra, which is nearly as much as a 2TB drive for the PS5.

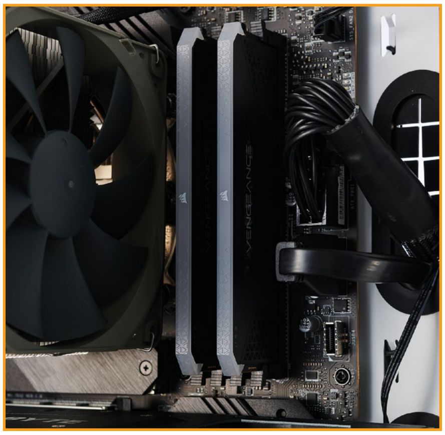
WINNER

**PCs**

CONSOLES

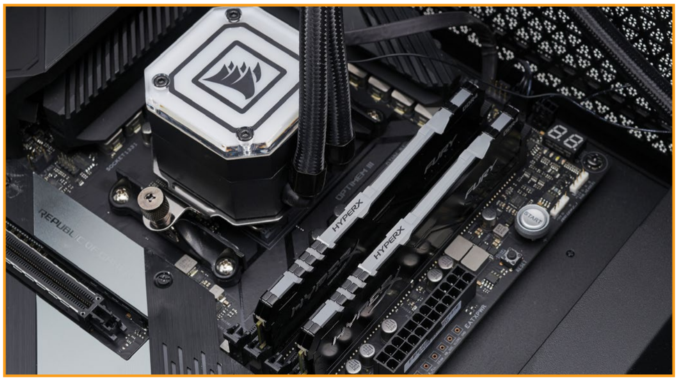
**No contest here. Anyone able to operate a screwdriver can easily upgrade the RAM and storage on a PC, with the option of CPU and GPU upgrades for those who want to go further.**

MAG
LIGHTNING GEN4 M.2
MORTAR



GEFORCE RTX
GIGABYTE
TOMAHAWK

**Upgrading a PC ranges from easy (RAM, GPU, SSD) to medium difficulty (motherboard, CPU, cooler).**



# OVERALL

The good news is that, no matter what you game on, the latest games consoles and PCs both offer some amazing experiences for gamers. There are now just so many options on how to play—you can stream games, play a mountain of free-to-play games, or pay a relatively low monthly fee and get immediate access to some of the best games ever made.

Never have games been more accessible to a wider audience than today, and given the price of the hobby in the 1990s and early 2000s, that's a real blessing. Now, if only we could actually get hold of any of these consoles and graphics cards, we'd be set.

However, if you're looking for the very best in gaming, we think that has to be on PC. With all of Microsoft's first-party titles hitting PC the same day as Xbox Series consoles and on Xbox Game Pass as well, the PC basically is an Xbox Series console in all but name. And with PlayStation Studios releasing *Horizon*, *God of War*, and *Days Gone* on PC, with *Uncharted* later this year, the best of PlayStation is also now available on PC. With free multiplayer, regular free game drops on Epic Games Store, and the ability to get console-level graphics from a PC under $1,000, the PC is still where it's at, and that's even before the launch of next-generation RDNA 3 and Nvidia 4000-series hardware. Suck it, console fans! ⏻

WINNER

**PCs**

CONSOLES

**You can't go wrong with either, but the PC offers the best gaming experience and the most versatility.**

# CENTERFOLD

PERFORMANCE GEAR LAID BARE

# Acer Predator CG7

**HAVE YOU EVER LOOKED** at your fancy-pants 4K PC monitor and thought 'gee, this is great, I wish my television was like this'? Well, Acer has you covered. The Predator CG7 is billed as a 'large format gaming monitor', but let's be honest: this is a gaming TV, and we love it. It even comes with a remote—bet your monitor doesn't have that.

A 42.5-inch 4K panel packed with gaming-led features and wrapped up in a slick Predator-branded chassis, the CG7 is somewhat unique as a huge gaming monitor. Most PC monitors greater than 40-inches are ultrawide, curved affairs rather than having a conventional widescreen aspect ratio.

Naturally, framerates and responsiveness are key for gaming, so this 4K screen offers a clean 144Hz refresh rate in its high-end model (or 120Hz if you want to spend a little less) along with 1ms Visual Response Boost for latency-free input. It supports Nvidia G-Sync to minimize tearing and artifacts as well as enabling variable refresh rate mode for best performance.

In practice, it's a gorgeous screen on which to play games and watch your favorite shows. VESA-certified DisplayHDR 1000 and a 90 percent DCI-P3 color gamut means that bright colors pop and blacks are brilliantly contrasted, with colorful games looking incredible (we played the original *Mirror's Edge* on it, and it looks fantastic).

A dual 10W speaker system at the rear of the screen provides room-filling sound on par with pricier television sets if you don't have your own sound system. All next-gen inputs are supported here, with HDMI 2.1, DisplayPort 1.4, and a USB hub that provides 2.0, 3.0, and USB-C ports. Whether you want a TV replacement or a new centerpiece for your gaming setup, the Predator CG7 can do it all. –CHRISTIAN GUYTON

## 1 BONUS BITS

Acer has squeezed some nifty extra features into the CG7, such as a light sensor that allows for adaptive brightness and even a movement sensor that wakes the display upon return if you leave the room. Finally, the monitor offers a whopping 178° viewing angle, so couch gaming with friends has never been easier.

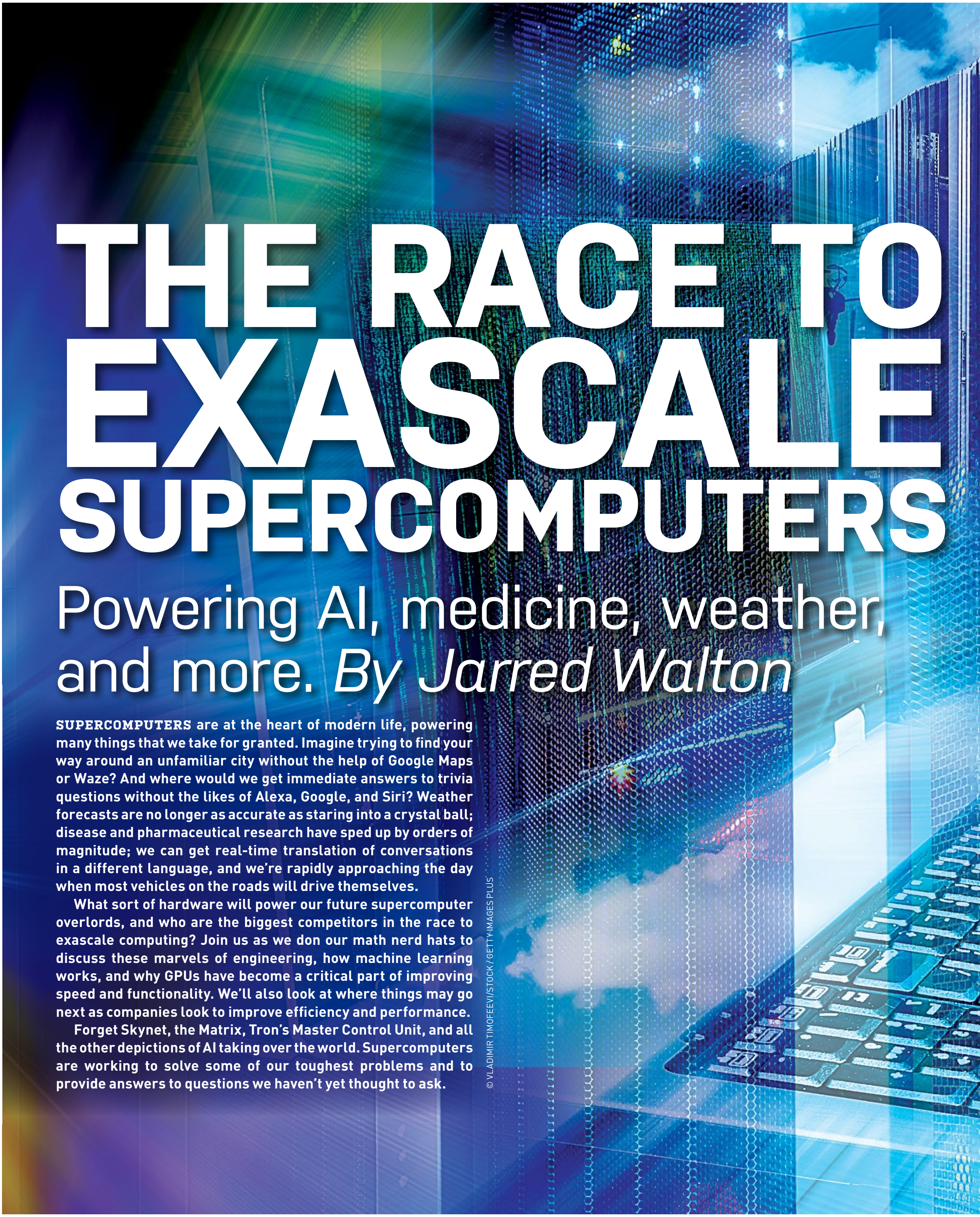
REDATOR
acer

## 3 LIGHT SHOW

Unsurprisingly for a gaming product, the CG7 has the option to attach up to four RGB lightstrips to the rear, with Acer's RGB Light Sense software allowing you to customize to your heart's content. You can choose from preset patterns, or synchronize the lighting to audio. There are even game sync options that allow the lighting to respond to in-game actions.

## 2 MOUNTED MAJESTY

Provided you have a sturdy wall, the CG7 supports VESA mounting with its removable base. We didn't try this out, but we reckon the CG7 would look right at home on a living room wall.



# THE RACE TO EXASCALE SUPERCOMPUTERS

## Powering AI, medicine, weather, and more. *By Jarred Walton*

**SUPERCOMPUTERS** are at the heart of modern life, powering many things that we take for granted. Imagine trying to find your way around an unfamiliar city without the help of Google Maps or Waze? And where would we get immediate answers to trivia questions without the likes of Alexa, Google, and Siri? Weather forecasts are no longer as accurate as staring into a crystal ball; disease and pharmaceutical research have sped up by orders of magnitude; we can get real-time translation of conversations in a different language, and we're rapidly approaching the day when most vehicles on the roads will drive themselves.

What sort of hardware will power our future supercomputer overlords, and who are the biggest competitors in the race to exascale computing? Join us as we don our math nerd hats to discuss these marvels of engineering, how machine learning works, and why GPUs have become a critical part of improving speed and functionality. We'll also look at where things may go next as companies look to improve efficiency and performance.

Forget Skynet, the Matrix, Tron's Master Control Unit, and all the other depictions of AI taking over the world. Supercomputers are working to solve some of our toughest problems and to provide answers to questions we haven't yet thought to ask.

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**SUPERCOMPUTERS** have gone by various names over the years. The original mainframe systems of the 1950s, 60s, and 70s were, in effect, supercomputers, though there weren't personal computers until the 1980s. In modern terms, a supercomputer just means an installation with a much higher level of performance than your typical PC or even high-end server.

Supercomputers typically occupy an entire data center, and while they are usually made up of thousands of servers called nodes, they're more than just a bunch of systems in the same room. All the individual nodes are linked together via high-speed networking solutions and are designed to work on massive data sets distributed across the nodes.

Because they are used for scientific research, supercomputers are typically classified by their performance in FLOPS (or flops), floating-point operations per second. But it's not just any old floating-point calculation, it's the 64-bit IEEE FP64 capabilities that are measured. Top500.org ranks the fastest and most efficient supercomputers twice per year, based on their performance in the Linpack test suite.

Starting in 1993, the fastest supercomputer was the CM-5/1024 that could perform many tens of billions of floating-point operations per second (gigaflops or GFLOPS). It used 1024 SuperSPARC 32-bit processors.

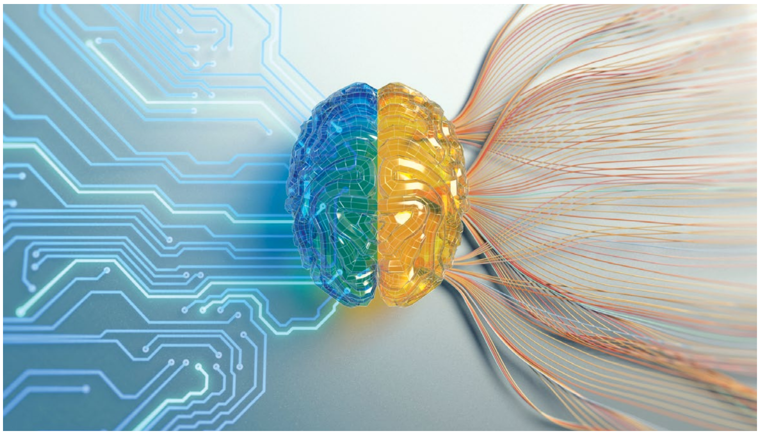
The first supercomputer to pass the one trillion FLOPS (teraflops or TFLOPS) mark was finally put into service in 1997—the ASCI Red with 7,264 Intel Pentium Pro processors. Just 11 years later, the supercomputer that first broke the petaflops (PFLOPS) mark was Roadrunner, using 12,960 PowerXCell 8i 9-core processors and 6,562 AMD Opteron CPUs—and yes, the PowerXCell was similar to the Cell Broadband Engine that powered the PlayStation 3.

Today, the fastest supercomputer based on Linpack performance is the Fugaku in Japan. It uses 48-core Fujitsu A64FX 64-bit ARM processors in staggering numbers. There are 396 racks with 384 nodes each, and another 36 racks with 192 nodes, where a 'node' consists of a single A64FX CPU. In total, there are 158,976 CPUs, crunching along at 2.0–2.2GHz. Each CPU is also paired with 32GB of HBM2 memory, delivering 1024GB/s of bandwidth. It delivered a result of 442 petaflops in Linpack in late 2021, though in 16-bit FP operations, it's potentially four times that fast, but more on that shortly.

By comparison, the fastest desktops running a single CPU and GPU might deliver computational performance in the 30–40 teraflops range, but that's in 32-bit floating-point. Most consumer GPUs barely have any FP64 capability, making them a poor choice for scientific workloads. The Radeon RX 6950 XT we review in this issue, for example, has 16 times more FP32 compute than FP32, while last month's GeForce RTX 3090 Ti has 64 times more FP32 than FP64 performance. Put another way, the Fugaku is about 275,000 times faster than the fastest gaming desktop right now. Now that's super.

Many countries and companies are now pushing toward the next step: Exascale—the ability to perform one quintillion FP64 operations per second, or 1,000 petaflops: one exaflop. Depending on the type of workload, some supercomputers have already passed this milestone but for FP64 computations, we're still only about halfway there. In fact, if you took the combined computational power of all the top 500 supercomputers and put them together, the result would only be around three exaflops. And yet, within the next year or so, we should see several exascale class supercomputers come online, more than doubling the aggregate computational power of the top 500.

## SIMULATING THE HUMAN BRAIN



Machine learning algorithms try to mimic the way neurons in the brain work.

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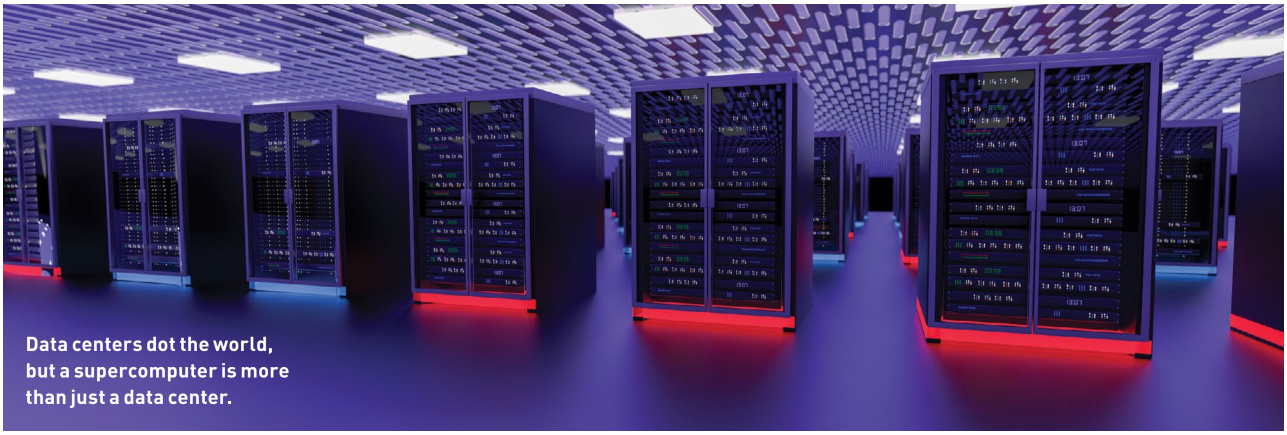
**If the goal is to create a machine that can show human levels of intelligence, simulating a human brain in real-time would be a good target. How much computational power does the human brain have, and how powerful would a supercomputer need to be to equal a human? It's a conundrum that has been researched and debated for decades.**

**Neural networks aren't new, and they have shown up in various forms over the years, like *Terminator's* Skynet. Back in the early 1980s, some thought it would only take a hundred gigaflops, or perhaps a few teraflops, to achieve artificial intelligence. For example, see Rudy Rucker's Ware *Tetralogy*, specifically the first novel *Software*, written in 1982, where an early 'shackled' AI ran at 100 gigaflops. Today, such estimates seem quaint, though incidentally, Rucker provided an updated estimate of 300 petaflops in 2005.**

**Typically, estimates are given in much broader terms. We have obviously long since passed the teraflops mark, and modern supercomputers run in the petaflops range for FP64, and well into the exaflops range in FP16 AI computations. Ray Kurzweil was hired by Google to work on machine learning and language processing back in 2012, and he estimated we need around 20 petaflops to simulate a human brain. Other estimates can be as low as one petaflop or as high as one zettaflop—a million petaflops.**

**The difficulty with simulating the human brain is that it does lots of things. We can walk, talk in many languages, recognize images, drive a car, and even write software to create artificial intelligence—or try to. The hardware alone is only half the solution, and we may have already passed the point where we could fully simulate a human brain. Now, all we need is the right software, which seems to be taking much longer to arrive.**



Data centers dot the world, but a supercomputer is more than just a data center.

**WHAT IS MACHINE LEARNING?**

Attempts to create artificial intelligence aren't anything new, and one of the first attempts at some form of AI came all the way back in 1958 with the perceptron. This was an image recognition machine and algorithm that used a 20x20 array of photocells as inputs. The aim was to train the system to be able to recognize certain objects or shapes, like differentiating between squares and circles.

A perceptron is an algorithm designed to mimic a neuron in the human brain. It takes a series of inputs—signals from other neurons—and then either activates a signal or doesn't activate it. At least, that's the simplified version of things. In practice, machine learning uses 'neurons' with many inputs to generate a weighted output, making things a bit fuzzier.

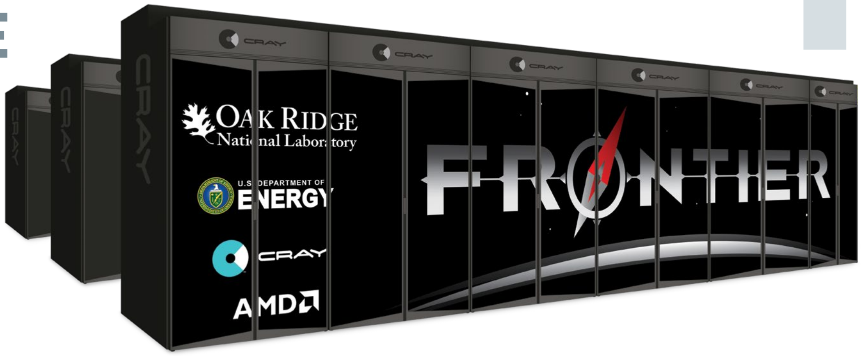
Mathematically, a function f(x) takes a dot product of a vector of weights w. In other words, it uses the sum of all the elements in two vectors of equal lengths, x and w. The elements in w can be assigned different weights that are adjusted over time, with a bias that helps determine the output. Adjusting those weights is the "learning" part of machine learning. Clear as mud? Let's put it a different way.

Think of the billions of neurons in a human brain, each with potentially thousands of input connections from other neurons. Our brains develop certain patterns over time, with a series of synapses firing that makes us think a certain food tastes spicy, or an object feels cold, or that shape in the distance represents our friend. These patterns are the weights that a machine learning algorithm attempts to determine.

## AMD'S EXASCALE AMBITIONS

AMD's EPYC processors packing up to 64 cores have proven to be extremely potent and popular within the server community of late. With its Milan CPUs and Aldebaran (MI250X) GPUs, AMD's lineup was impressive enough to garner two exascale contracts for Frontier and El Capitan. Frontier is already in the process of coming online and features Zen 3-based CPUs with MI250X GPUs, while El Capitan is slated to use Zen 4-derived CPUs and potentially a future AMD Instinct GPU—we say 'potentially' because it's not clear if AMD will have anything better than MI250X available any time soon.

Exact details of the two supercomputers aren't available, though Frontier is supposed to have over 100 cabinets or 'pods' if you're comparing to Nvidia. Frontier will use Shasta blades with a single 64-core 'Trento' 7A53 CPUs and four MI250X GPUs. Each MI250X GPU is capable of up to 48 teraflops of FP64 vector performance, but MI250X also features matrix hardware (i.e. tensor cores). A single MI250X can do up to 96 teraflops of matrix FP64 operations, and up to 383 teraflops of FP16/BF16, which is higher than Nvidia's H100 FP64 performance.



The AMD-powered Frontier supercomputer is slated to be the first to break the exaflops barrier, more than doubling the current fastest installation.

The performance target for Frontier is '1.5 exaflops', using over 9,000 nodes. With each node delivering around 192 teraflops of FP64 vector performance, simple math gives us the theoretical 1.73 exaflops.

That's not even using the potentially higher performance FP64 matrix hardware, which doubles performance again, and for AI workloads using BF16 Frontier has up to 13.8 exaflops on tap. How do you like them apples, Nvidia?

El Capitan, meanwhile, has a performance target of over two exaflops. Again, considering the Frontier hardware, it's not difficult to imagine 96-core Zen 4 'Genoa' processors paired with either current or next-generation Instinct GPUs easily reaching that target. Basically, take Frontier and add 30 percent more nodes, though we're sure it's more complex...

© AMD, KWARKOT/ISTOCK / GETTY IMAGES PLUS

There are many variations on how to go about training a neural network. Initially, it starts in a blank state with either zero or randomized weights on the various inputs and outputs. The goal of machine learning is to get the network into a state where it can provide useful information and feedback. This is an iterative process that gets repeated millions of times, slowly working toward an ideal state that it may never quite reach.

Supervised learning is one common approach to machine learning. It relies on massive data sets of labeled inputs and desired outputs. For example, take image recognition, where the network is supposed to recognize a cat, dog, house, human, or car. The algorithm is fed a series of labeled images and its answers get checked. If it gets the answer wrong, for example, if it thinks a picture of a dog is a cat, the weights of the network neurons get adjusted and it moves on to the next image. Over time, the network gets better at recognizing the various images.

At the other end of the spectrum, unsupervised learning deals with unlabeled and uncategorized data, and the network looks for commonalities. Are there patterns and groupings in the data that have meaning? This type of machine learning is often used with statistics, though it can be applied to other fields as well.

The third type of machine learning is reinforcement learning. This is often used with game theory and the algorithm works to maximize some form of 'reward'. In chess, for example, the value of the pieces can be set and the legal moves defined, and the algorithm's goal is to come up with moves that maximize its points while reducing the opponent's points. Reinforcement learning is also commonly used with autonomous vehicle applications.

If that all sounds a bit vague, it's because we're operating at a very high level. There are hundreds of books and papers about machine learning, and people can spend their entire life studying the topic. But whatever the type of algorithm, the important thing to understand is that machine learning requires a lot of math, specifically matrix dot products.

Dealing with the inputs and output of a single neuron might not seem too hard, but imagine thousands of neurons with their input weights and outputs, all interacting with each other. The algorithms end up performing massive amounts of multiplication and addition operations.

That's the real crux of determining how fast a particular system is for machine learning: How many multiplication and addition calculations can it perform in a second? It also means that if you want a 'smarter' system for machine learning, all you need to do is throw more computational power at the problem. That brings us to the next topic.

### HOW PRECISE ARE AI CALCULATIONS?

Supercomputers have largely focused on improving performance while working with highly accurate FP64 numbers. Machine learning ends up tossing a lot of that work in the rubbish bin. While it's certainly possible to run machine learning algorithms with the precision of FP64, research and practical applications have determined that it's not necessary. Cutting down the precision from FP64 to FP32 makes almost no difference, FP16 can also work just fine, and companies including Nvidia and Intel are going as low as 8-bit integer and floating-point formats. Actually, Nvidia has been experimenting with 4-bit and even 2-bit formats and finding some situations where that's sufficient.

The benefit of using less precise numerical formats is that there's a lot less data to move around and fewer bits to toggle in a processor. In practice, that means FP32 calculations can be done at twice the speed of FP64 work, FP16 is double the speed

## INTEL'S AURORA, BETTER LATE THAN NEVER

**The Aurora supercomputer has a lengthy history. Originally announced in 2015 and slated to launch in 2018 with a target performance of 180 petaflops, it was later delayed to 2021 and was to be the first exascale computer. Designed and built by Intel and Cray for the Argonne National Laboratory, Intel's difficulties with the transition to 10nm lithography ultimately contributed to even more delays.**

**The current schedule calls for Aurora to go online sometime this year, though the AMD-powered Frontier is now expected to be the first exascale supercomputer. Given Frontier isn't expected to be fully available to researchers until early 2023, we wouldn't be surprised to see Aurora finally debut next year. In the meantime, Intel has upgraded the target performance for Aurora, and it's now supposed to exceed a whole two exaflops.**

**Aurora will consist of over 9,000 nodes, with each node running dual Sapphire Rapids Intel Xeon processors—that's the Xeon equivalent of Alder Lake, more or less, but with AVX512 support fully enabled. Each node will also contain six Ponte Vecchio GPUs. Those GPUs deserve additional detail.**

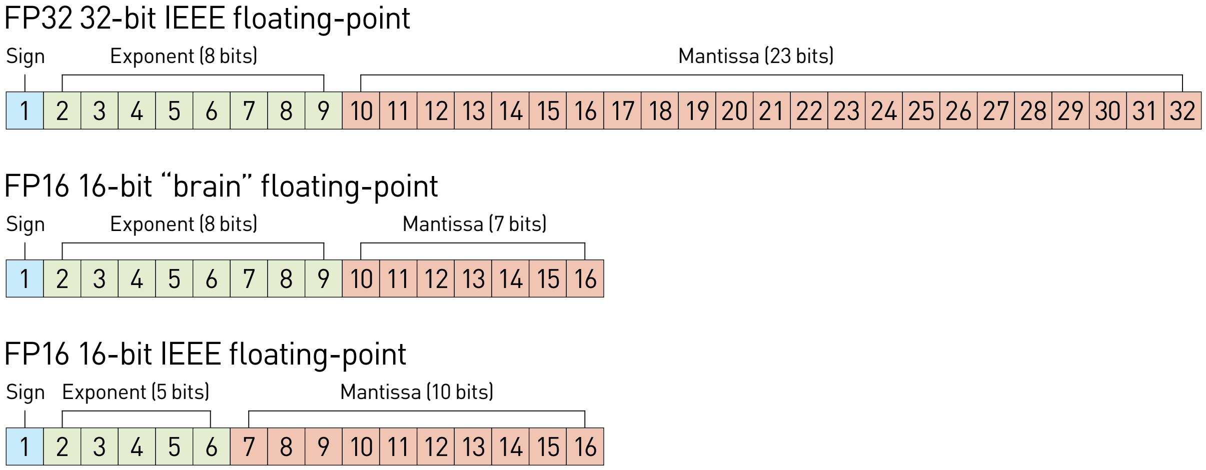
**Intel's Aurora supercomputer will finally go online sometime in the next year.**

© INTEL

**Ponte Vecchio will feature a whopping 47 active tiles and 3D chip stacking technology. Some of the tiles are manufactured by Intel, some by TSMC and others. Five different process nodes in total are used for Ponte Vecchio, and we can't help but wonder if that may not be part of the reason for the additional delays.**

**Intel claims performance of over 45 teraflops FP32 for Ponte Vecchio, which has the same FP64 throughput as FP32. With six GPUs per node, that yields roughly 270 teraflops, and the CPUs also have some compute resources. Aurora will probably have 24 pods with 12 racks each, and 32 server blades (nodes) per rack. That would make 9,216 nodes and 2.5 exaflops. Small wonder Aurora could use as much as 60MW of electricity.**

### STANDARDIZED 16-BIT AND 32-BIT FLOATING-POINT NUMBER FORMATS

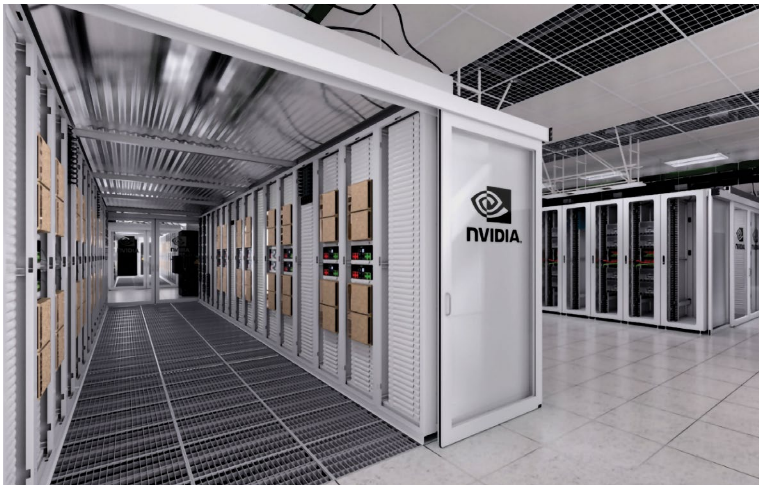

FP32 32-bit IEEE floating-point
Sign
Exponent (8 bits)
Mantissa (23 bits)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
FP16 16-bit "brain" floating-point
Sign
Exponent (8 bits)
Mantissa (7 bits)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FP16 16-bit IEEE floating-point
Sign
Exponent (5 bits)
Mantissa (10 bits)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

of FP32, and FP8 doubles the speed yet again. If certain machine learning operations can use FP8 instead of FP64, the overall throughput improves by a factor of eight. But the hardware needs to be designed to support the less precise formats—previous-generation GPUs for example didn't natively support FP16 and would have to simulate FP16 operations using FP32 hardware.

The consensus right now for AI algorithms seems to be converging on 16-bit floating-point as the data format of choice. It balances speed with levels of precision that are sufficient for the task at hand. One change that was adopted in more recent years has been a new 16-bit format called bfloat16 or BF16, for "brain floating-point."

The standard FP16 uses one sign bit, a 5-bit exponent, and a 10-bit mantissa. FP32 in contrast has the same sign bit, an 8-bit exponent, and a 23-bit mantissa. The exponent provides numerical range, while the mantissa determines the precision.

## NVIDIA GOES ALL-IN ON AI


Nvidia's Selene supercomputer debuted on the Top500 in position six with 63 petaflops FP64, but its FP16 performance hits a theoretical 2.8 exaflops.

© NVIDIA

**While scientific research using FP64 remains important, Nvidia is betting big on the increasing importance of AI workloads. Its current Selene supercomputer already ranks among the top ten fastest for traditional workloads, but in AI performance Nvidia says it can do 2.8 exaflops. If Selene sounds potent, just wait for the upcoming Eos supercomputer, built on Nvidia's latest Hopper H100 processor.**

**Eos will consist of 18 DGX H100 SuperPODs, each with 32 DGX H100 servers. The servers will be powered by dual AMD EPYC processors, but Nvidia doesn't even make a point of mentioning what CPUs are used as they are child's play compared to the GPU hardware. There are eight H100 GPUs per DGX H100 or 4,608 GPUs in total.**

**Eos looks pretty tame in terms of its traditional supercomputer Linpack potential. Each H100 has a theoretical performance of 60 teraflops FP64, giving a maximum of 276 petaflops. That's enough for second place on the current top 500, but the AI potential is much greater.**

**In FP16/BF16 workloads, Eos provides up to 9.2 exaflops of compute. Nvidia is taking this a step further by supporting FP8 number formats, which doubles again the theoretical performance to 18.4 exaflops.**

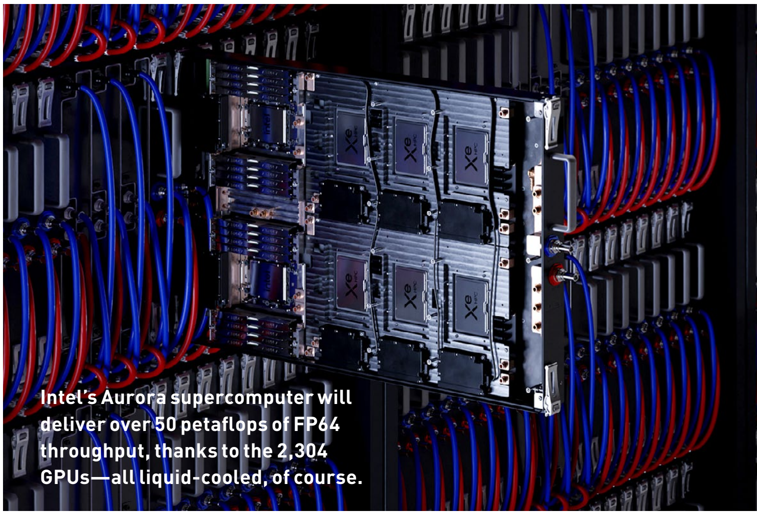
**Other companies are pursuing AI as well, but Nvidia's CEO Jensen Huang is particularly bullish on where AI is going. Where traditional weather modeling and forecasts have been done using FP64, Nvidia has trained an AI model to predict weather patterns and it is claimed that it can achieve comparable accuracy in a fraction of the time, thanks to the power of deep learning.**

Machine learning can benefit from a greater range at the cost of precision, which is why BF16 uses the same 8-bit exponent but with a much narrower 7-bit mantissa. Hardware can still run BF16 operations at twice the speed of FP32, and machine learning algorithms tend to work a bit better than with regular FP16 calculations.

The basic concept of a supercomputer isn't too difficult. Take a base unit that can be replicated thousands of times, then link it all together. Combine it with an operating system that knows how to schedule workloads across all the nodes and manage communication between them and you're done. Kind of.

One of the problems with scaling supercomputers to higher speeds is the Von Neumann bottleneck. All digital computers need to deal with this in some way, and the basic issue is getting the necessary data needed for computation into the appropriate place so that the calculation can be performed. Your AMD Ryzen or Intel Core CPU has several layers of cache of different speeds and capacities to help with this, but supercomputers take things to a new extreme. When an algorithm deals with huge amounts of data, spread across thousands of nodes, getting the inputs and outputs routed across the network becomes a major problem. Many of the fastest supercomputers use HBM2 memory to increase bandwidth, but that's only for local computations. The network infrastructure and storage subsystem must be equally robust. Gigabit Ethernet isn't going to cut it.

Japan's Fugaku includes Tofu Interconnect D on each CPU as an example. That consists of six 28Gbps interfaces (6.8GB/s after encoding overhead) connected to the Tofu Network Router via 10 ports with two lanes each. There are over 200,000 Tofu cables used in Fugaku, about half of which are fiber optic cables that run between the racks, with around 893km of cable length in total.



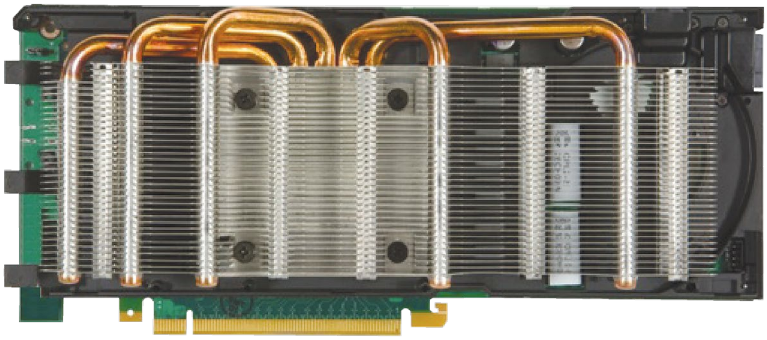
Intel's Aurora supercomputer will deliver over 50 petaflops of FP64 throughput, thanks to the 2,304 GPUs—all liquid-cooled, of course.

### SCALING POWER ALONG WITH PERFORMANCE

There are still limits to scaling and, as the number of nodes in a supercomputer and the size of the data sets being worked upon, increase, eventually, the amount of power consumed in looking up data starts to eclipse the power used for the actual computations, Von Neumann again. While the performance offered by newer supercomputers has continued to scale rapidly over the years, it's telling that the fastest supercomputers are less efficient overall compared to smaller installations.

Fugaku has an efficiency of 15.42 GFLOPS/W, and the second fastest supercomputer, Summit, isn't far behind at 14.72

## GPUS AREN'T JUST FOR GAMES



In 2010, Nvidia's Tesla M2050 was the first GPU targeted at supercomputers. It packed 3.1 billion transistors and 515 gigaflops of FP64 performance.

© NVIDIA, INTEL

**The advent of modern GPUs has radically altered the supercomputer landscape. Video cards used to focus primarily on spitting out pixels to your display, but when programmability entered the picture, it was only a matter of time before that computational power would come to be put to other uses.**

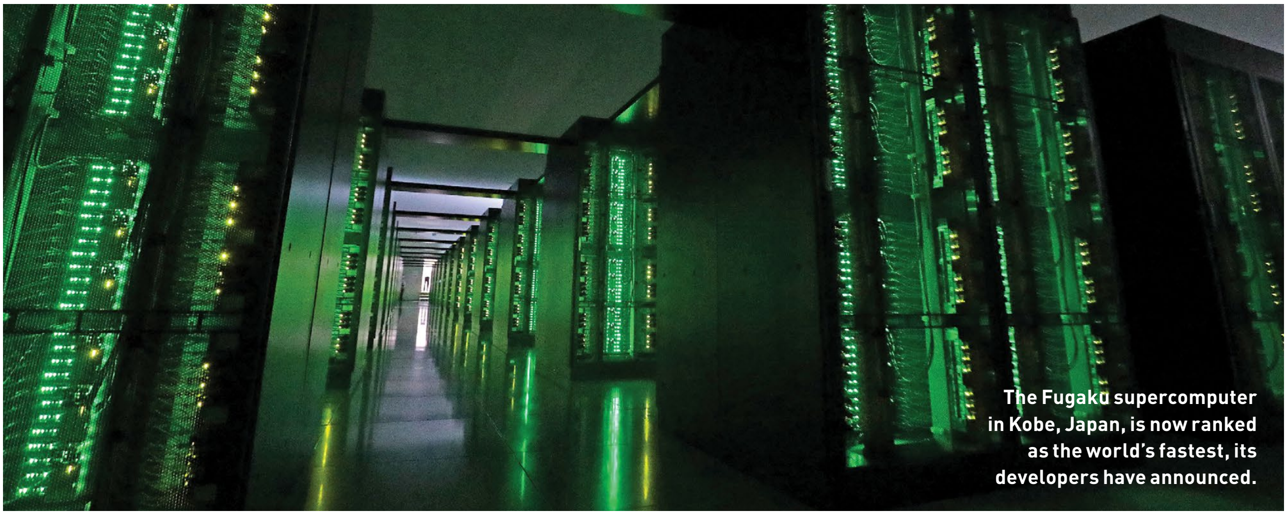
**CPUs remain important for general-purpose workloads, running the operating system, browsing the web, and even powering much of the logic behind the graphics in our games. Trying to make a computer where everything ran on the GPU would knock performance in certain tasks back to the proverbial stone age. But if you want to do lots of similar calculations in parallel, that's precisely what a GPU does for graphics.**

**The 3D game worlds of our day can include millions of polygons. Turning all that geometry into a meaningful two-dimensional image on your monitor requires a lot of matrix math calculations.**

**Each point on a polygon consists of X, Y, and Z coordinates, and changing the viewing angle and position of objects within the virtual world is done via linear algebra using matrix multiplication and addition.**

**As such, GPUs have gone from a few simple processing cores back in the late-1990s to our modern chips with thousands of cores, each capable of doing a massive heap of math calculations.**

**Not surprisingly, the high-performance computing world took notice. GPUs first started showing up in supercomputers around 2007, and it didn't take long for them to gain traction. By 2010, the world's fastest supercomputer, China's Tianhe-1A, packed in 7,168 Nvidia Tesla M2050 GPUs with 14,366 Intel Xeon CPUs. Today, the ratio has shifted decidedly more in favor of GPUs, with the Summit supercomputer having three times as many GPUs as CPUs.**



The Fugaku supercomputer in Kobe, Japan, is now ranked as the world's fastest, its developers have announced.

GFLOPS/W. That's half of what the most efficient supercomputers on the Green 500 list achieve. Only one, Perlmutter, ranks in the top ten for both the Top 500 and the Green 500 lists.

It's also interesting to look at power use over the years. Roadrunner, the fastest supercomputer in 2008, used about 2,345kW of power, while Fugaku consumes over ten times as much at 29,900kW. Put another way, one hour of Fugaku running at capacity uses about as much power as three typical households would consume during an entire year.

Things aren't going to get better as supercomputers push into the exascale range. The first three exascale computers in the US—Frontier, Aurora, and El Capitan—are all slated to use anywhere from 20MW to 60MW of power. One megawatt is enough to supply around 100 homes with power, so combined, the three will use as much power as 12,000 households.

We've talked about the slowing down of Moore's Law and the end of Dennard scaling in the past. Some might say there's still room for continued exponential growth—the doubling of transistors every couple of years, for example. But if the first exascale supercomputers already use tens of megawatts, we can't help but wonder how much power will be needed in a decade or two when we're talking about zettascale supercomputers.

## MEET GOOGLE'S TPU V4, KIND OF

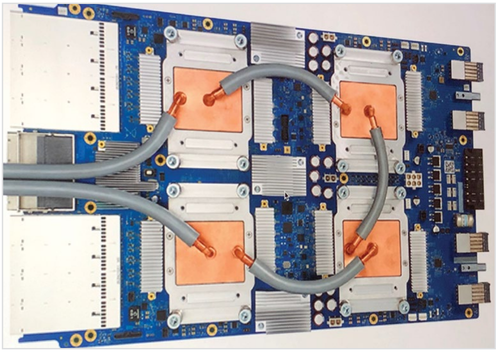
Google is another company that has put a huge effort into AI research. Its search engine continues to be the best in the world, and its DeepMind technologies have created several impressive tools, including AlphaGo, the first AI to beat one of the best humans at Go— a feat some thought would be impossible for the foreseeable future. In 2016, AlphaGo took down one of the top players, who retired in 2019 declaring AI to be "an entity that cannot be defeated."

Google created its first custom Tensor Processing Unit (TPU) back in 2015, with a performance of 23 teraops — Google appears to have focused on INT8 rather than floating-point formats, so it's teraops instead of teraflops. It used the TPU internally in its data centers to power AlphaGo, AlphaZero, parsing of text for Google Street View, and more. It made later-generation TPUs available via its Google Cloud platform.

Last year at Google I/O, CEO Sundar Pichai spoke about the fourth generation of TPU, stating that it provides twice the performance of TPU v4. In its data centers, Google has deployed TPU v4 pods, each with 4096 TPU v4 chips, but it has never divulged the low-level specs. TPU v3 reportedly offers 90 teraops of performance, however, so TPU v4 should be roughly double that — at less than half the power consumption. That's less powerful than Nvidia's A100, never mind the H100, but again Google isn't providing concrete details yet.

One advantage of the TPU is that it completely omits support for technologies that Nvidia continues to include in its GPUs. There's no support for FP64, or even FP32. The chips are focused on accelerating Google's TensorFlow software and little else. It may not work well on all algorithms, but considering Google's expertise in AI research, the TPU appears quite competitive.

Google also offers an Edge TPU with power use of just 2W and performance of 4 teraops. It's used in the Pixel 4 smartphone and is available in Edge computing devices. Rather than focusing on training AI models, the Edge TPU focuses on inference—running an already trained model.



Google TPU v3 launched in 2018, with TPU v4 coming in 2021, but Google hasn't said much about its latest hardware.

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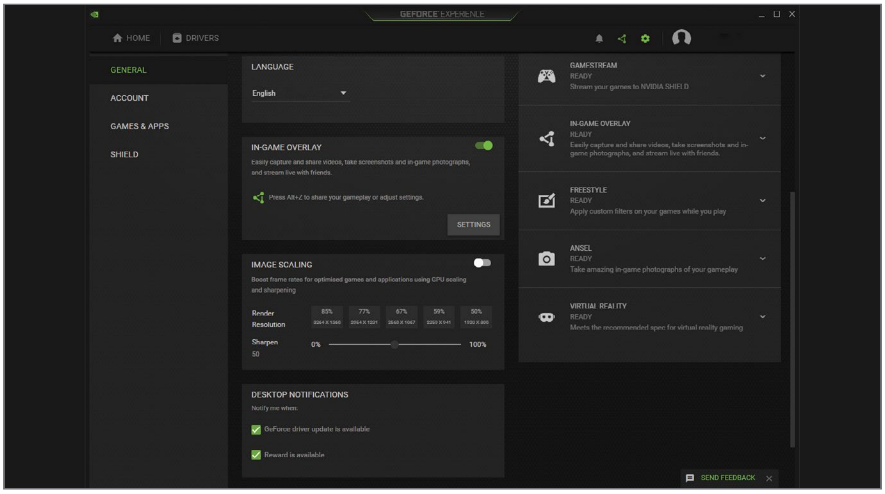
# HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

## TIP OF THE MONTH


GEFORCE EXPERIENCE

HOME | DRIVERS

GENERAL
ACCOUNT
GAMES & APPS
SHIELD

LANGUAGE
English

IN-GAME OVERLAY
Easily capture and share videos, take screenshots and in-game photographs, and stream live with friends.
Press Alt+Z to share your gameplay or adjust settings.
SETTINGS

IMAGE SCALING
Boost frame rates for optimised games and applications using GPU scaling and sharpening
Render Resolution: 85% 3264 X 1360 | 77% 2954 X 1201 | 67% 2560 X 1067 | 59% 2259 X 941 | 50% 1920 X 800
Sharpen 50: 0% – 100%

DESKTOP NOTIFICATIONS
Notify me when:
☑ GeForce driver update is available
☑ Reward is available

GAMESTREAM
READY
Stream your games to NVIDIA SHIELD

IN-GAME OVERLAY
READY
Easily capture and share videos, take screenshots and in-game photographs, and stream live with friends.

FREESTYLE
READY
Apply custom filters on your games while you play

ANSEL
READY
Take amazing in-game photographs of your gameplay

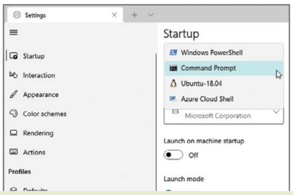
VIRTUAL REALITY
READY
Meets the recommended spec for virtual reality gaming

SEND FEEDBACK

### AUTO GPU OVERCLOCKING

If you're running an Nvidia RTX card and have the GeForce Experience app, then there is a somewhat hidden feature that you may have missed. In the settings, make sure that the in-game overlay is turned on and hit 'ALT + Z' to open it up. Then click performance and enable automatic tuning. If you haven't already overclocked your GPU, this should help.

## MAKE – USE – CREATE



**64**
Tips for mastering Windows 11 Command Line

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Machine of the Month: Apple Macintosh II

**70**
Add a splash of neon light to your photos in GIMP

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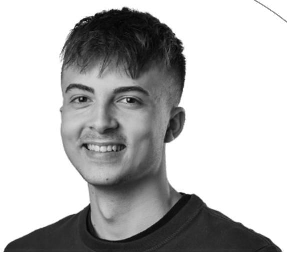


SAM LEWIS
STAFF WRITER

## ENTERING THE LIQUID-COOLING LOOP

My former colleague and *Maximum PC* editor, Zak Storey, was back on his old stomping ground last month to help show me the ropes of some high-level, water-cooled PC building.

We opted for hard tubing, which requires bending and shaping. After a few attempts that were nothing short of embarrassing, I eventually got the hang of it. You certainly appreciate the craftsmanship that goes into these PCs and makes them so special. It was the most rewarding build I've done and I can't wait to try more ambitious watercooling in future. It's a welcome reminder that learning new skills is fun!

But as good as it is, this overkill liquid-cooled PC hasn't yet had a chance to stretch its legs fully. So far, I've only been running *Lego Star Wars: The Skywalker Saga* on it—thankfully, it runs on max settings with nothing but a whisper coming from the machine. Once I've finished that, I'm going to play through *Elden Ring* on this rig, which should test the machine more.

After seeing the benchmarks, I have high expectations, but I'm not one to jump from game to game. The completionist in me means I have to finish one game before even thinking about the next!

↘ submit your How To project idea to: editor@maximumpc.com

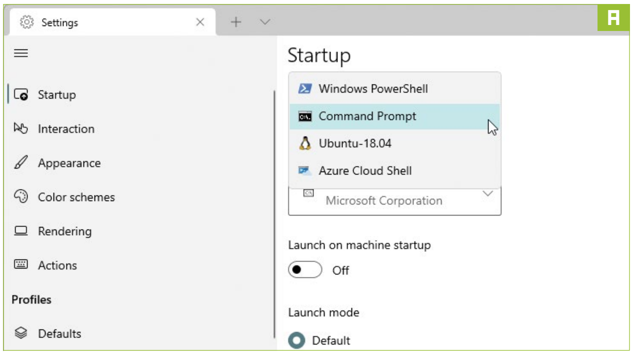
# Advanced Win11 tips: Command Prompt

### YOU'LL NEED THIS

**ANY WINDOWS PC WILL DO**
Windows 10 release 20H1 (or later) to use the Windows Terminal; otherwise, tips should all work in the old Command Prompt console.

**ONCE UPON A TIME**, Microsoft's operating system, MS-DOS, was solely based on the Command Prompt. It remained a fundamental part of early versions of Windows but, these days, you have to dig deep to find it. Not only has it been supplanted by the more user-friendly Windows desktop, it's not even the only command-line shell available. In addition to adding support for Linux, Microsoft has also unveiled PowerShell. Despite this, however, the Command Prompt remains a valuable tool in anyone's armory.

For the purposes of this tutorial, we're going to focus on using the Command Prompt in Windows itself to examine your system, perform key checks and fix various problems. Even if you prefer to use PowerShell, you can still read along, because PowerShell supports everything in the Command Prompt—and then some. We'll examine its unique tools in more depth in a future issue, but by focusing on the Command Prompt now, you can ensure you have all the fundamentals should you need to get to those essential troubleshooting tools. – **NICK PEERS**



1

### CHOOSE YOUR CONSOLE

While the Command Prompt retains its own dedicated console (type 'cmd' into the Search box, then click 'Run as administrator' to launch it), you can also access it through the new Windows Terminal application by right-clicking the Start button and choosing 'Windows Terminal (Admin)'.

» Windows Terminal works with all command-line tools in Windows, but creates a PowerShell instance by default. Click the down arrow next to its tab and you'll reveal options to open further tabs using other shells, including Command Prompt (press Ctrl + Shift + 2 as a shortcut) and any Linux shells you've installed as part of the Windows Subsystem for Linux.

» The good news is that you can choose which shell is the default when opening Windows Terminal: click 'Open Settings' followed by the 'Default profile' dropdown under Startup to select Command Prompt from the list [**Image A**]. Click Save and the next time you open Windows Terminal (or a new tab via the + button), it will open a Command Prompt console by default.

» The Command Prompt console is also accessible outside of Windows via the Advanced Start Options menu, typically when Windows fails to boot. Should you need to reboot to it from Windows for a spot of deep-seated troubleshooting, type shutdown /r /o into Windows Terminal and hit Enter.

2

### NAVIGATE YOUR HARD DRIVE

By default, you're placed in your own user directory after opening Windows Terminal. Start by typing dir and hit Enter for a list of all the files and folders in the current directory. Add the '/a' flag followed by an attribute to change what's shown, including '/a:h' for hidden files, '/a:r' for read-only files, '/a:d' for directories, and '/a:h' for system files.

» Want to visualize how a specific directory is broken down? Use the 'tree' command on the current directory or specify a directory, such as tree c:/windows/system32 [**Image B**].

» How about moving between directories? Unsurprisingly, the standard 'cd' command is used here, using the following syntax:

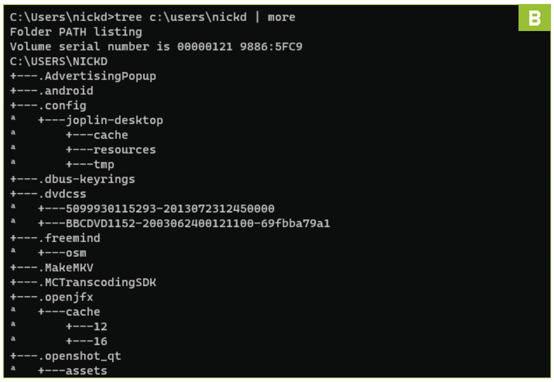
- cd "←full path→" jump to that specific directory within the current drive (eg, cd "C:\Windows\System32")
- cd ←variable→ substitute a directory with an environment variable (cd %appdata%)
- cd ←directory→ enter the named directory inside the currently selected folder (cd documents)
- cd .. – move up a level

» If you want to switch to a different drive, you'll find the cd command has no effect—simply type the drive letter (such as d:) and hit Enter, then use the 'cd' command to navigate to your desired folder.

3

### WORK WITH FILES

You can manage files from the Command Prompt using: 'copy', 'move', 'rename', and 'del'. All work with individual files as well as wildcards (del *.* is the nuclear option for all files within the current folder, for



```
C:\Users\nickd>tree c:\users\nickd | more
Folder PATH listing
Volume serial number is 00000121 9886:5FC9
C:\USERS\NICKD
+---.AdvertisingPopup
+---.android
+---.config
ª   +---joplin-desktop
ª       +---cache
ª       +---resources
ª       +---tmp
+---.dbus-keyrings
+---.dvdcss
ª   +---5099930115293-2013072312450000
ª   +---BBCDVD1152-2003062400121100-69fbba79a1
+---.freemind
ª   +---osm
+---.MakeMKV
+---.MCTranscodingSDK
+---.openjfx
ª   +---cache
ª       +---12
ª       +---16
+---.openshot_qt
ª   +---assets
```

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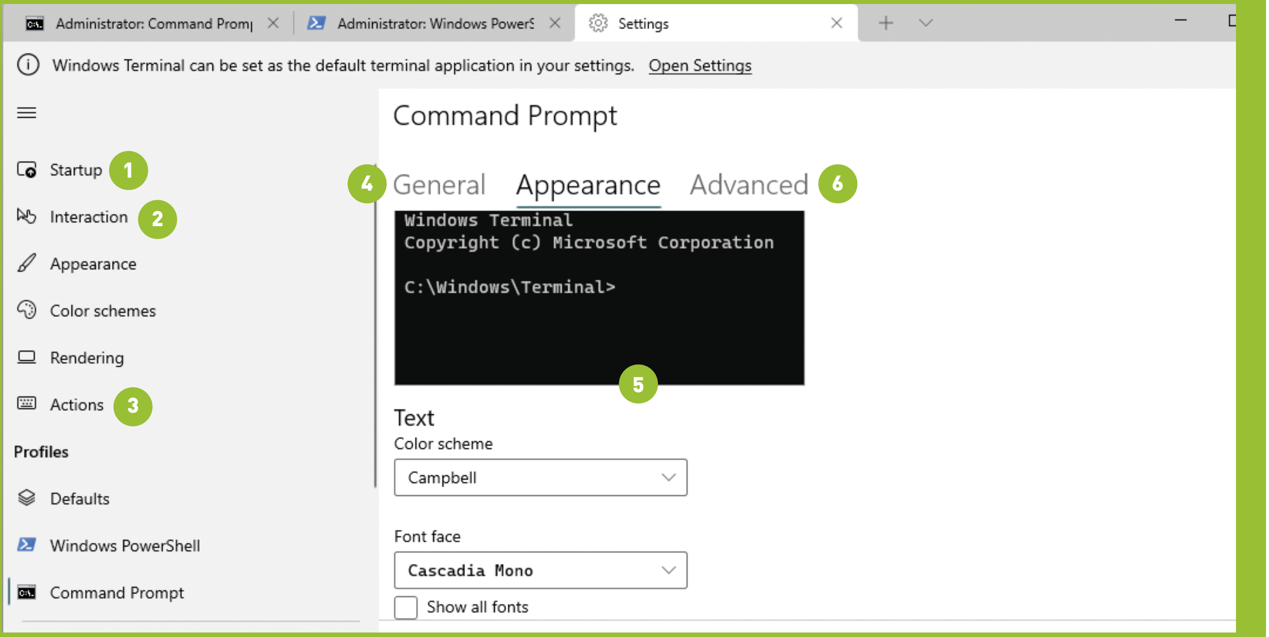
# CUSTOMIZE WINDOWS TERMINAL


Administrator: Command Promp
Administrator: Windows PowerS
Settings
Startup
1
Interaction
2
Appearance
Color schemes
Rendering
Actions
3
Profiles
Defaults
Windows PowerShell
Command Prompt
4
General
Appearance
Advanced
6
5

Windows Terminal can be set as the default terminal application in your settings. Open Settings

Command Prompt

```
Windows Terminal
Copyright (c) Microsoft Corporation

C:\Windows\Terminal>
```

Text

Color scheme: Campbell

Font face: Cascadia Mono

☐ Show all fonts

**1. STARTUP**
Select this to set what happens when opening Windows Terminal. Choose the Command Prompt under Default profile to launch that by default.

**2. INTERACTION**
Flick the 'Automatically copy selection to clipboard' switch to On to speed up copy and paste using the Windows Terminal. If copying rectangular selections, flick 'Remove trailing white-space…' to On too.

**3. ACTIONS**
Use this dialog to view and change existing keyboard shortcuts, plus set new ones from dozens of available commands and options.

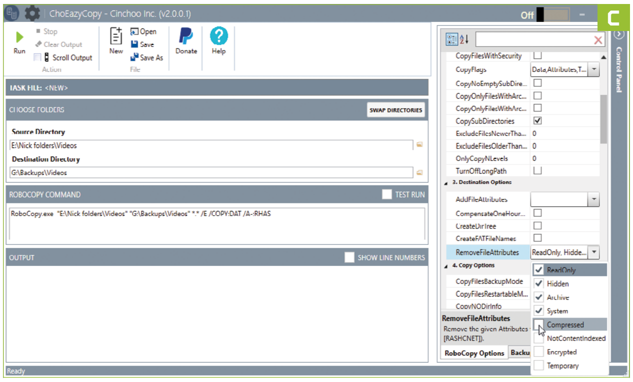
**4. GENERAL TAB**
The options here include allowing you to rename the Command Prompt tab. You can also set a different starting directory instead of your personal user folder.

**5. APPEARANCE TAB**
Change the color scheme, font (family, weight, and size), cursor type, and even set a background, among other options.

**6. ADVANCED TAB**
Useful options here include setting a limit to the history of previous commands (9001 by default). You can also change the notification from a sound to a visual flash and specify when the Terminal window closes.

example). You can manage folders too: 'md' creates a folder, while 'rmdir' removes it. If you plan to delete a folder that isn't empty, use rmdir /s <–directory–> to delete it and its contents.

» That's useful if you're troubleshooting outside of Windows, but with File Explorer on hand most of the time, it can be overkill. That said, you might want to use Command Prompt to, say, copy all text files from a folder without touching anything else. Try copy *.txt c:txtbackup /V. The optional /V flag verifies the copied files to ensure they've been written correctly.


ChoEazyCopy - Cinchoo Inc. (v2.0.0.1)
Off
Run
Stop
Clear Output
Scroll Output
Action
New
Open
Save
Save As
File
Donate
Help
TASK FILE: <NEW>
CHOOSE FOLDERS
SWAP DIRECTORIES
TEST RUN
OUTPUT
SHOW LINE NUMBERS
Control Panel
RoboCopy Options
Backu
Ready

Source Directory: E:\Nick folders\Videos

Destination Directory: G:\Backups\Videos

ROBOCOPY COMMAND

```
RoboCopy.exe  "E:\Nick folders\Videos" "G:\Backups\Videos" *.* /E /COPY:DAT /A-:RHAS
```

CopyFilesWithSecurity ☐
CopyFlags: Data,Attributes,T...
CopyNoEmptySubDire... ☐
CopyOnlyFilesWithArc... ☐
CopyOnlyFilesWithArc... ☐
CopySubDirectories ☑
ExcludeFilesNewerTha... 0
ExcludeFilesOlderThan... 0
OnlyCopyNLevels 0
TurnOffLongPath ☐
3. Destination Options
AddFileAttributes
CompensateOneHour... ☐
CreateDirTree ☐
CreateFATFileNames ☐
RemoveFileAttributes: ReadOnly, Hidde...
☑ ReadOnly
☑ Hidden
☑ Archive
☑ System
☐ Compressed
☐ NotContentIndexed
☐ Encrypted
☐ Temporary
4. Copy Options
CopyFilesBackupMode
CopyFilesRestartableM...
CopyNODirInfo

RemoveFileAttributes
Remove the given Attributes [RASHCNET]).

© CHOEAZYCOPY

» Another handy feature offered by 'copy' is the ability to merge multiple files into one—this obviously only works with files that can be merged in this way, so won't work with Microsoft Word documents, but will work with text. Use the following syntax:

```
copy file1.txt+file2.txt+file3.txt newfile.txt
```

» The cipher command allows you to wipe the free space in a folder by writing random data to it. Delete files first, then navigate to the folder and type:

```
cipher /w:<path>
```

» Cipher can also be used, as its name implies, to encrypt and decrypt files too.

## 4

## MAKE USE OF ROBOCOPY

Command Prompt is home to a powerful tool called robocopy, which among other things allows you to mirror two locations for backup purposes, a bit like RAID. All associated attributes—including date and time stamps—are preserved, but the command is packed full of filters and options that can be impossible to grasp without the relevant reference information (https://docs.microsoft.com/en-us/windows-server/administration/windows-commands/robocopy) to one side. Even then, one mistake could have consequences.

## COMMAND PROMPT 101

What can you do with the Command Prompt? There are dozens of useful commands you can input, and we'll be showcasing the best of them in this tutorial. Before going any further, it helps to understand how commands are broken down, known as the command syntax.

There's the command itself, of course, but it's usually followed by one or more options, some compulsory (in that you must choose at least one), others optional. These options are context-sensitive—they might refer to a path or filename, as is the case with the 'recimg' command for creating a recovery image, or they may refer to various 'flags', which instruct the command to work in a specified way—for example, adding -v to a command like 'driverquery' usually tells it to output the command's results in 'verbose' or detailed mode rather than as a basic summary. Note, unlike with Linux, flags aren't case sensitive, so typing -v or -V results in the same thing.

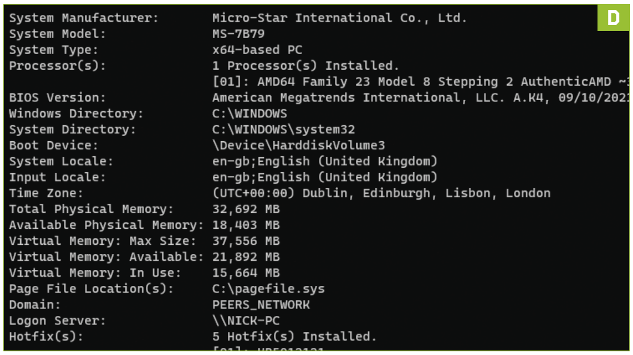
There are many commands to learn and master—visit https://docs.microsoft.com/en-us/windows-server/administration/windows-commands/windows-commands for a complete list, or use the /? flag for a quick reference within Windows Terminal itself.

» If you find the idea of robocopy appealing but are put off by the complexity, never fear: several GUI frontends have been developed, including the free and open-source ChoEazyCopy (https://github.com/Cinchoo/ChoEazyCopy). Simply select your source and destination directories, then use the options box on the right to select the various flags and options on offer. A handy robocopy command box [**Image C**] reveals what the equivalent robocopy command would be in the Command Prompt, enabling you to use ChoEazyCopy as an education tool.

## 5 TROUBLESHOOT YOUR PC

Let's start with the 'chkdsk' tool for checking drives for errors. Use chdsk on its own to perform a quick scan of the current drive to verify all is well, or type chkdsk d: to scan a different drive. If problems are found, use the '/r' flag (so chkdsk c: /r) to both fix problems and attempt to recover readable information from bad sectors. If the drive is in use, you'll be prompted to schedule the check for the next time you restart Windows. Press Y and reboot to have a full check performed.

» Want a summary of information about your system? Use the 'systeminfo' command, which aside from the usual stuff, can reveal useful snippets like when Windows was first installed and which hotfixes have been installed [**Image D**]. It can also be used to see if your PC is capable of Hyper-V virtualization.



D

```
System Manufacturer:       Micro-Star International Co., Ltd.
System Model:              MS-7B79
System Type:               x64-based PC
Processor(s):              1 Processor(s) Installed.
                           [01]: AMD64 Family 23 Model 8 Stepping 2 AuthenticAMD ~
BIOS Version:              American Megatrends International, LLC. A.K4, 09/10/202
Windows Directory:         C:\WINDOWS
System Directory:          C:\WINDOWS\system32
Boot Device:               \Device\HarddiskVolume3
System Locale:             en-gb;English (United Kingdom)
Input Locale:              en-gb;English (United Kingdom)
Time Zone:                 (UTC+00:00) Dublin, Edinburgh, Lisbon, London
Total Physical Memory:     32,692 MB
Available Physical Memory: 18,403 MB
Virtual Memory: Max Size:  37,556 MB
Virtual Memory: Available: 21,892 MB
Virtual Memory: In Use:    15,664 MB
Page File Location(s):     C:\pagefile.sys
Domain:                    PEERS_NETWORK
Logon Server:              \\NICK-PC
Hotfix(s):                 5 Hotfix(s) Installed.
```

» Use the 'driverquery' command to get information about all the drivers on your system—software too, such as those installed by your security software and virtualization tool. These are marked as 'File System' drivers, and if you want more information, use the -v flag for detailed information about each driver, including where its files are on your hard drive.

» The -v flag produces an awful lot of information, so be sure to check the tips and tricks box to find out how to more efficiently review this, either by scrolling a page at a time or by outputting it to a text file.

## 6 FIX PROBLEMS WITH SFC

Another well-known tool is the System File Checker and most people know that running sfc /scannow should, in theory, detect any corrupt system files and replace them with working backups. It's not always successful—if you get a message telling you that Windows Resource Protection couldn't fix all the corrupt files it found, the DISM tool is your go-to tool for getting things working again:

```
dism /Online /Cleanup-Image /ScanHealth
```

» If your source image gets the all-clear, issue the following command before running 'sfc /scannow' again:

```
dism.exe /Online /Cleanup-image /Restorehealth
```

» If your source is corrupt, but 'repairable', create an ISO file using the Windows Media Creation Tool, then double-click the ISO file to mount it as a virtual drive.

» From here, open the drive in File Explorer and verify whether install.wsm or install.esd is present in the sources folder. Return to Command Prompt and type the following, substituting E with the actual drive letter and replacing 'install.wim' with 'install.esd' if applicable:

```
dism /get-wiminfo /wimfile:E:\sources\install.wim
```

» You'll see a list covering all available editions of Windows [**Image E**], including Home (index 1) and Pro (index 6). Once you've worked out which number matches your edition of Windows, issue the following command, substituting 1 with the relevant index number:

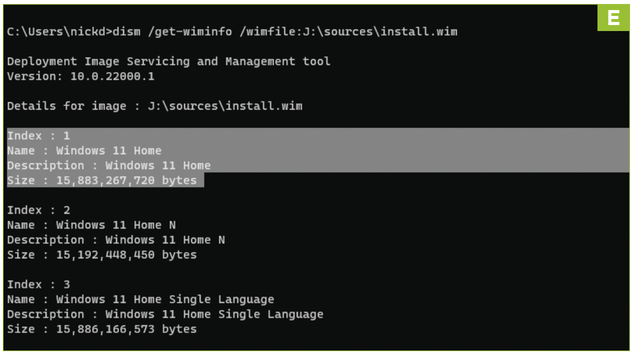
```
dism /Online /Cleanup-Image /RestoreHealth /
Source:wim:E:\sources\install.wim:1 /limitaccess
```

» This should fix any lingering corruption, enabling you to use 'sfc /scannow' again.

## 7 EXAMINE POWER-RELATED ISSUES

The 'powercfg' command is your go-to when troubleshooting power-related problems. Start with powercfg /a for a summary of which sleep states are supported on your PC.

» Next, use powercfg /h on and powercfg /h off to enable and disable hibernation. If you've disabled it



E

```

C:\Users\nickd>dism /get-wiminfo /wimfile:J:\sources\install.wim

Deployment Image Servicing and Management tool
Version: 10.0.22000.1

Details for image : J:\sources\install.wim

Index : 1
Name : Windows 11 Home
Description : Windows 11 Home
Size : 15,883,267,720 bytes

Index : 2
Name : Windows 11 Home N
Description : Windows 11 Home N
Size : 15,192,448,450 bytes

Index : 3
Name : Windows 11 Home Single Language
Description : Windows 11 Home Single Language
Size : 15,886,166,573 bytes
```

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because of drive space concerns, the good news is that Microsoft has optimized the file in recent years, so the hiberfil.sys is now around 40 percent the size of your installed RAM, that's a relief for those with small boot drives and 32GB of RAM. It's also possible to trim the hiberfil.sys file so it's just 20 percent of your installed RAM (powercfg /h /type reduced), but you'll need fast startup enabled.

» The command can also generate detailed information—use the '/energy' flag to create a report that highlights potential energy efficiency and battery life issues [**Image F**]. Once created, a file called energy-report.html will be saved to the directory you're currently in. Before analyzing it to find out why your PC won't stay asleep, however, try powercfg /lastwake, which reveals the last device to wake your computer.

» Laptop users might want to try the '/batteryreport' flag, which like /energy saves a report you can view in your web browser. This gives you a full overview of your battery's health as well as a graph showing its usage over the past 72 hours.

## 8 TROUBLESHOOT NETWORK PROBLEMS

There are other, more focused, information tools as well. Use ipconfig to get information about your local network settings – use the /all flag for more detailed information.

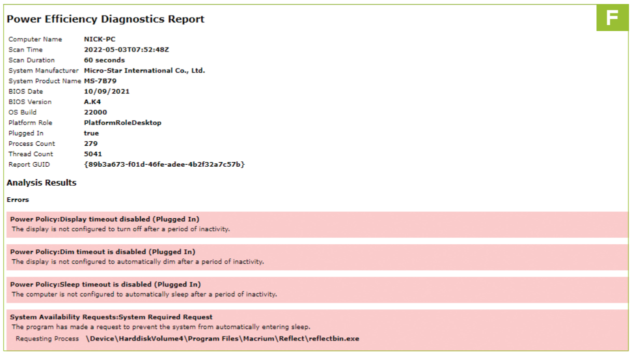
» ipconfig can also be used to fix certain connectivity problems—use '/release' to release the IPv4 address ('/release6' works with your network's IPv6 address if applicable), and '/renew' or '/renew6' to effectively reset it. Try ipconfig /flushdns when struggling to resolve domain names over the internet.

» Where more than one network interface is present (as is often the case on PCs with virtualization software installed), you can also specify the adapter after your flag: ipconfig /renew Ethernet, for example.

» Another command that can also prove useful when troubleshooting network and internet connectivity is 'ping', which can be used to verify connections between local network devices or websites. Use it in conjunction with the device name, its local IP address, web address, or remote IP address. If you ping using a domain or device name, you will also be told its IP address (such as 199.232.194.114 for our sister website, techradar.com, for example).

» For a detailed route between your computer and an IP address, substitute 'ping' with tracert to see which IP addresses your connection travels through to reach its destination. The command is also handy for spotting bottlenecks that are slowing the connection.

» Want to know what ports are open on your PC and where they point to? Then why not use the 'netstat' command. Try netstat -b while running as an administrator if you want to find out more about which program or process has opened which port. It's a slow process, but worth it if you're wondering why a particular port is open.


F

**Power Efficiency Diagnostics Report**

| | |
|---|---|
| Computer Name | NICK-PC |
| Scan Time | 2022-05-03T07:52:48Z |
| Scan Duration | 60 seconds |
| System Manufacturer | Micro-Star International Co., Ltd. |
| System Product Name | MS-7B79 |
| BIOS Date | 10/09/2021 |
| BIOS Version | A.K4 |
| OS Build | 22000 |
| Platform Role | PlatformRoleDesktop |
| Plugged In | true |
| Process Count | 279 |
| Thread Count | 5041 |
| Report GUID | {89b3a673-f01d-46fe-adee-4b2f32a7c57b} |

**Analysis Results**

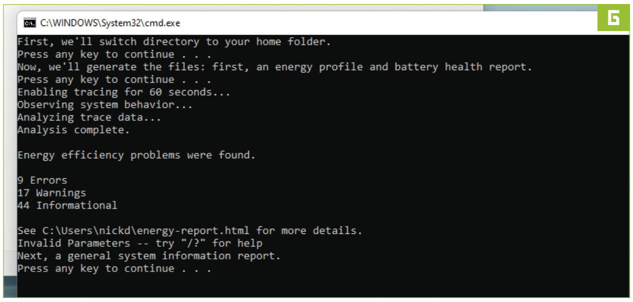
**Errors**

**Power Policy:Display timeout disabled (Plugged In)**
The display is not configured to turn off after a period of inactivity.

**Power Policy:Dim timeout is disabled (Plugged In)**
The display is not configured to automatically dim after a period of inactivity.

**Power Policy:Sleep timeout is disabled (Plugged In)**
The computer is not configured to automatically sleep after a period of inactivity.

**System Availability Requests:System Required Request**
The program has made a request to prevent the system from automatically entering sleep.
Requesting Process **\Device\HarddiskVolume4\Program Files\Macrium\Reflect\reflectbin.exe**


G

C:\WINDOWS\System32\cmd.exe

```
First, we'll switch directory to your home folder.
Press any key to continue . . .
Now, we'll generate the files: first, an energy profile and battery health report.
Press any key to continue . . .
Enabling tracing for 60 seconds...
Observing system behavior...
Analyzing trace data...
Analysis complete.

Energy efficiency problems were found.

9 Errors
17 Warnings
44 Informational

See C:\Users\nickd\energy-report.html for more details.
Invalid Parameters -- try "/?" for help
Next, a general system information report.
Press any key to continue . . .
```

## 9 WORKING WITH BATCH FILES

While PowerShell is the recommended shell for automation, you can still use batch files in Command Prompt to process a sequence of repetitive commands quickly and easily. Create them in any text editor—place each command with its options on a separate line and when you come to save the file, make sure it's given a .cmd extension instead of .txt.

» Command Prompt includes several commands specifically designed for using in batch scripts. Let's start with 'pause', which when inserted into your script results in a 'Press any key to continue' message. The 'echo' command allows you to display text on-screen, while inserting '@echo off' at the top of your batch file prevents the commands from appearing on-screen in Windows Terminal as they're run.

» Other useful commands include 'call', which allows you to call a second batch file from within the first, plus several commands that provide interactivity to the end-user in the form of choices: 'choice', 'set', 'if' and 'goto'.

» Batch files can be run by either double-clicking them in File Explorer or right-clicking them and choosing 'Run as administrator' to run with elevated privileges. You'll see the traditional Command Prompt window appear, and it disappears when the script completes. ⏻

## COMMAND PROMPT TIPS AND TRICKS

The Windows Terminal is packed with time-saving features, some of which made their way into the default Command Prompt console. When using the latter, you should find QuickEdit Mode is enabled by default (if not, right-click the console bar and choose Defaults). This makes it easy to select and copy text from the console quickly using the mouse. Place the text where you wish to paste it in the console and right-click again.

Many commands generate pages and pages of data—to save you the onerous task of scrolling back up to review them, add the '| more' option onto the end of offending commands to force them to show the first page then pause—from here, press Enter to move down a line at a time, or press the spacebar to scroll through the next page. Alternatively, redirect the information to a text file with the → switch—for example, driverquery -v →drivers.txt will create the file in your current directory.

Want to clear the screen buffer and start with a fresh new 'page'? Type cls and hit Enter. Finally, use the up and down cursor keys to scroll through previous commands to speed up text entry.

# Machine of the Month: Apple Macintosh II

**ALTHOUGH THE MACINTOSH II** is rarely mentioned in retro computing circles, it introduced monumental changes, bringing color graphics, a shift towards a 32-bit architecture, and multi-monitor support. For the retro enthusiast, the Macintosh II line has a sizeable library of excellent applications and multimedia, industry-leading desktop publishing software, as well as cult favorites in gaming and "edutainment". – **JOHN KNIGHT**

### YOU'LL NEED THIS

**A COPY OF MINI VMAC**

Plus working system ROM and OS image. https://www.gryphel.com/c/minivmac/download.html

## 1 DEVELOPMENT

When the original Macintosh launched in 1984, despite its elegant styling and interface, the computing world was disappointed to find few opportunities for hardware expansion, and graphics only in black and white.

» In 1985, engineers Michael Dhuey and Brian Berkeley began work on a sequel, without the permission or knowledge of Steve Jobs, who led the Macintosh division at the time. Against Jobs' wishes, this new machine would feature color graphics, and in a move back towards the openness of the Apple II, easily accessible expansion slots, using MIT's NuBus system.

» After Jobs was fired in September 1985, the Macintosh II enjoyed open and official development under the new project head, Jean-Louis Gassée. On the 2nd March 1987, the Macintosh II had its debut appearance at the AppleWorld Conference, before shipping to the public in April.

» The Macintosh II ditched the small all-in-one design in favor of a PC-like desktop case with separate components. This was also the beginning of Apple's expensive era, where Macintosh computers were marketed as premium products, aimed at elite users and desktop publishing professionals. The base model cost $3,898, with only an 800KB floppy drive, but a 40MB hard drive model cost an eye-watering $5,498—more than $13,000 in today's money.

» Inside, the Mac II sported a 32-bit Motorola 68020 CPU running at 16 MHz, combined with a 68881 FPU. RAM was 1MB as standard, expandable up to 8MB. Graphically, it was capable of 16.7 million colors and a maximum resolution of 640x480 (at 256 colors). Customers could choose between a cheaper 12-inch black and white screen, or a highly-praised 13-inch monitor based on Sony Trinitron technology. Multiple monitors could be attached and windows could be dragged between screens.

» For an operating system, the Mac II was initially lumbered with System 4.1—a single-tasking relic from the 16-bit era used by other Macintosh models that relied on external software workarounds for multi-tasking.

## 2 SOFTWARE

Desktop publishing is the Mac II's strongest point. Having a 16.7 million color palette back then was a revelation for photo editing, where users could finally enjoy true color rendering. Adobe Photoshop (1990) got its start on the Mac II and shared the platform with desktop publishing stalwart QuarkXpress (1987), plus a version of Microsoft Word 5.0 (1991).

» Gaming-wise, the Motorola CPU had a weak point with 3D games, though more powerful models did receive an enhanced port of *Wolfenstein 3D* (1994), and there was the system's all-time classic first-person shooter, *Marathon* (1994).

» However, the Macintosh II had many classic 2D games, from *Civilization* (1992) and *Where in Time is Carmen Sandiego?* (1990) to fantasy RPG *Realmz* (1994), Japanese sci-fi platformer *Thexder* (1990), and the graphically sharpest version of *Flashback* (1992) on any system. There is of course the obligatory port of *Prince of Persia* (1992), which is a particularly sleek version.

## 3 LEGACY

Initially, things went well. Between the Macintosh II and Macintosh SE, Apple finally sold a million Macs in 1988. The easy access to the machine's internals opened up a new market for third-party components, and the upgrades kept coming with a bewildering number of model lines.

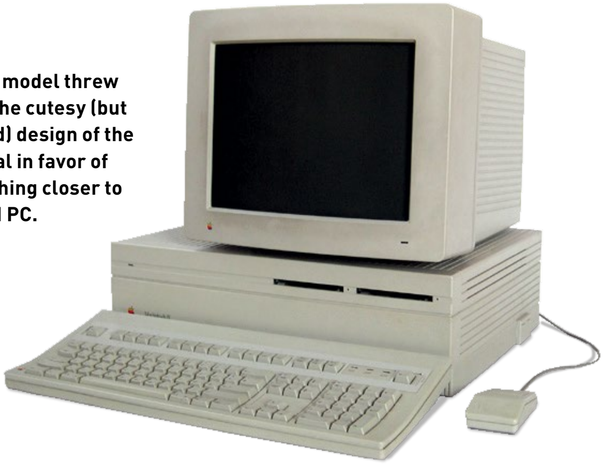
» In September 1988, the Macintosh IIx arrived, with a faster 68030 CPU. A hard drive and the new 1.4 MB "SuperDrive" floppy were now standard, for $7,700. These machines were becoming seriously expensive, and this would soon backfire. Commodore and Atari sold computers with the same CPUs for dramatically cheaper prices, but Apple wanted to be seen as superior and more sophisticated.

» In April 1990, Apple released the top-of-the-line Macintosh IIfx. This "wicked fast" powerhouse not only had a ridiculous 40MHz clock speed but had more efficiency per clock cycle and exotic hardware to push the Motorola CPU to its limits. While the base model was already expensive at $8,969, a full-spec machine cost $12,000—that's over $23,000 in today's money.

» Expense aside, Apple's "32-bit" label was causing serious problems with its customers. Despite having a 32-bit CPU, earlier models were stuck in an awkward

» *Marathon* (1994) provided a Macintosh-exclusive alternative to *Doom* and established developers Bungie.

© BUNGIE



» This model threw away the cutesy (but limited) design of the original in favor of something closer to an IBM PC.

## FINDING SOFTWARE

For a huge archive of abandonware software, check out macintoshgarden.org, which often provides handy .DSK and .IMG formats. There is a great collection of software archive links at vintagemacmuseum.com, but you will quickly run into a problem: most Mac software comes in .HQX format, which doesn't work with Mini vMac.

You can either try the more advanced (and less stable) Basilisk II emulator or, alternatively, you can visit: www.macintoshrepository.org, where you will find instructions for how to convert these files under a page called 'How to wrap loose old Mac files into a disk image'.

"24-bit" space, due to legacy components and software. This prevented the line from using the full 32-bit capabilities of its CPU, kept the RAM limit stuck at 8MB instead of 128MB, and caused software crashes and incompatibilities with 16-bit software in 32-bit environments.

» In 1989, the Macintosh IIci was the first to introduce a proper 32-bit system, capable of addressing 128 MB of RAM. Hardware upgrades were released to make older machines truly 32-bit, but software workarounds such as Mode32 (1991) by Connectix eventually allowed 32-bit operation and full RAM access, before Apple included their own software 32-bit enabler in System 7.1.

» The last Macintosh to wear the "II" nameplate was the Macintosh IIvx in 1992, before the line was discontinued in October 1993. Ultimately, the Macintosh II line was too expensive to sell in large numbers. Microsoft's bundling of Windows 3.x with computers ensured that the lower end of the market stuck with PCs, which might explain why we can't find sales numbers.

### 4 EMULATION

Macintosh emulation can be difficult, but we've streamlined the process as best we can. The two main emulators are Mini vMac and Basilisk II. Advanced users should try Basilisk II, but Mini vMac is easier to get started and more stable, so we'll use that.

» Before emulating the Macintosh II you need a system ROM, an image of Macintosh OS, and a copy of StuffIt Expander (everything in Mac world uses StuffIt). Legally, we can't recommend system ROMs or OS images unless you own the original products. But if you are in the clear, archive.org has a collection of Macintosh system ROMs. 'Mac II FDHD & IIx & IIcx' ROM works best.

» As for the OS, for compatibility's sake, we would recommend grabbing both System 6 and 7. Visit macintoshgarden.org and there are software entries entitled "Mac System 6 Collection" (tweaked specifically for Mini vMac), and "Mac OS 7.5.3 (for emulators)".

### 5 GETTING STARTED

Once you have all the prerequisites, head to the Mini vMac website and open the Download page. Click the link 'Download Macintosh II Variations'.

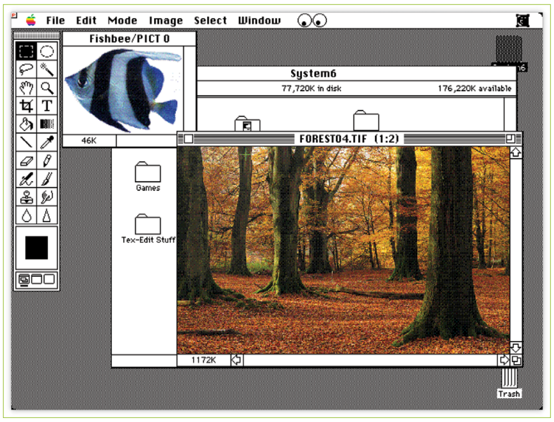
» The Windows ZIP file contains a single executable file called Mini vMac.exe. The Linux package contains a single executable that you may be able to run just by clicking on it. Otherwise, open a terminal and enter:

```
$ ./Mini\ vMac
```

» Once started, Mini vMac will display an error about not finding a ROM image. Drag your chosen system ROM onto the Mini vMac window, and if your ROM is recognized there will be a loud beep and a floppy disk icon. This is a normal Macintosh screen—it wants a system boot disk. Click and drag your OS image onto the window and, all going well, your OS should boot.

» Once your OS has loaded, you can explore disk images by dragging them onto the emulator window. If the image mounts successfully, a disk icon will appear on the desktop. If Mac OS says the disk image isn't readable, click Eject. Do not click Initialize—you may wipe out the image file.

» Firstly, Mini vMac runs at 8x speed by default. To change the speed, press Ctrl + S, then while keeping Ctrl held down, press Z. To make the window fullscreen, press Ctrl + F.



» The Macintosh II's advanced color graphics paved the way for the very first version of Adobe Photoshop.

## SPECIFICATIONS

APPLE MACINTOSH II (1987)

| | |
|---|---|
| CPU: | Motorola 68020 @ 16Mhz |
| RAM: | 1–8MB, 128MB |
| Launch price: | $3,898 |
| Graphics: | 640x480 maximum resolution, maximum 16.7 million colors |
| Storage: | 3.5-inch floppy, 800 KB–1.4 MB, plus 40MB and 80MB hard disk upgrades |
| OS: | System 4.1–System 7.5.5 |
| Released: | March 1987 |
| Production: | 1987–1993 |

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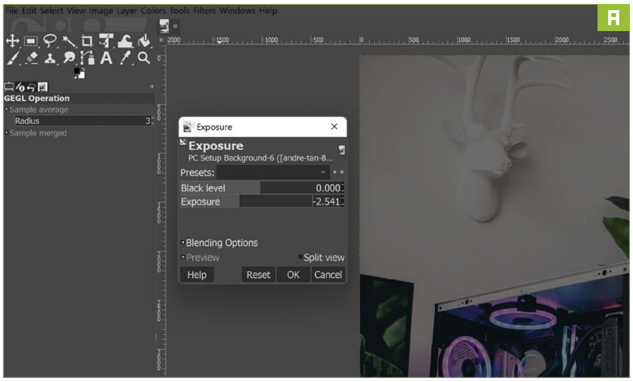
# GIMP neon line emphasis

### YOU'LL NEED THIS

**GIMP 2.1**
www.gimp.org
OS: Windows 7 or newer

**THERE ARE AN ALMOST INFINITE** range of uses for image editing applications. For many, the ability to make minor edits such as adding filters, color adaptations, and the odd manipulation is sufficient reason to invest in some software. On the other hand, a more powerful application, such as Adobe Photoshop or GIMP, gives the user more scope to edit imagery and create pieces of artwork. Photoshop is now on a subscription-based payment plan, which may be a financial barrier to the beginner or more casual user, however, GIMP is not only free, but it's a great starting point to get into more advanced areas of image manipulation. Test the waters and see whether this is a hobby you enjoy—and even if you could turn it into your profession..

In this tutorial, we'll be creating artwork using neon lines to enhance a photo. This technique has been used for video thumbnails, posters, flyers, album artwork, and banners. Like most tutorials, you can use these skills to your own advantage and apply them to other media. You can use any image (within reason) for this tutorial, although it does help if you have a subject focal point as this is what we will be emphasizing using these neon lines. As usual, we are using a royalty-free image from Unsplash, specifically an photo by Andre Tan. We are going to take his PC setup photo and add some attention-grabbing effects to it. –**SAM LEWIS**


A
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OK
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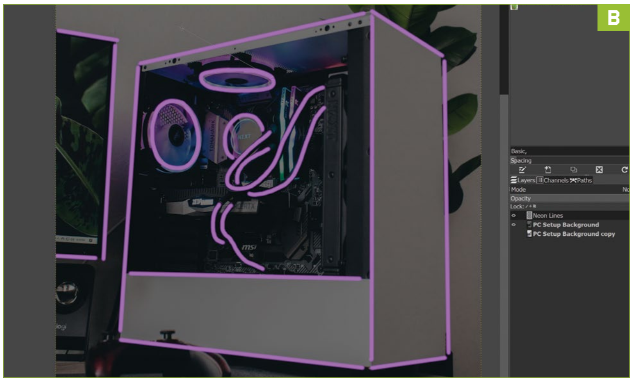

B
Layers
Channels
Paths
Mode
Opacity
Lock:
Neon Lines
PC Setup Background
PC Setup Background copy

## 1 FOR THE EXPOSURE

The first thing we always have to do is to bring our image into GIMP and rename the file to something applicable. We renamed our layer to 'PC Setup Background'. It's important to keep your layers organized in photo editing software.

» To make our neon lines pop more, we are starting by editing this background image and darkening it a little to mute the colors. This will create greater contrast between the original image and the neon colors that will make it stand out. If we ever need to go back and edit the original image again, we make sure that this is duplicated, locked, and hidden.

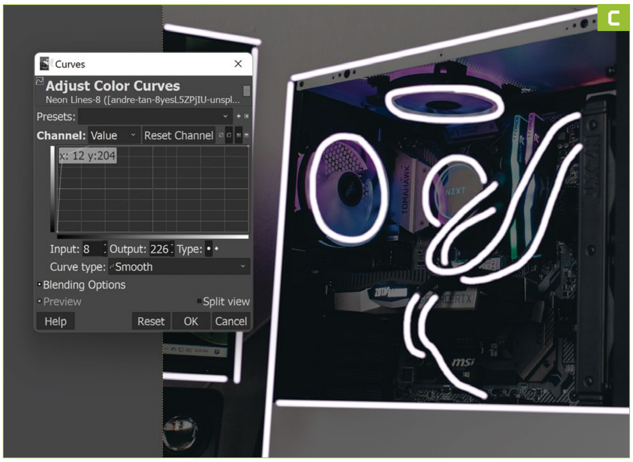
» Now, select the main layer, then go to the color tab at the top and click on exposure [**Image A**]. Then when this window appears, reduce the exposure a fraction to darken your image.

## 2 NEON LIGHTS

Now that our image is set up and ready to go, we can start to have a bit of fun with it. What you have to think about here is what part of the image you want to bring the attention to, as this will be the part we want to highlight with neon.

» Once you've figured this out, choose a color. We opted for neon pink, but you could equally use green or orange. Create a new layer for your neon lines and then use the brush tool to paint over the lines you want [**Image B**].

» Follow the edges of the main shapes to create this image. You don't have to be too accurate, the hands-on element brings in a neon paint effect to the image. As you can see, we followed the edge of the monitor, the PC, and some of the important PC components. We used some straight lines but followed these focal points loosely.


C
Curves

Adjust Color Curves
Neon Lines-8 ([andre-tan-8yesL5ZPjIU-unspl...
Presets:
Channel: Value
Reset Channel
x: 12 y:204
Input: 8 Output: 226 Type:
Curve type: Smooth

Blending Options
Preview
Split view
Help
Reset
OK
Cancel

© GIMP

## 3

### DUPLICATE THE LAYER

Once we've finished drawing lines, we need to duplicate this layer and rename it. This layer will be where we get our glow from. After duplicating the layer, bring this 'glow' layer below the original neon lines layer. Select the original layer and head to the color tab at the top.

» In this dropdown menu, select desaturate, then desaturate again, and hit OK. This will technically be our neon tubing. We are desaturating this layer as the color will be coming from the glowing layer behind.

» Finally, on the original neon lines layer, we need to head back to the colors tab [**Image C**], and curves and then bring this curve to the top left to create a gleaming white effect.

## 4

### LET IT GLOW

We're now set to create our neon glow. On this glow layer, we need to blur it for the color to bleed underneath the neon tubing effect we have just created on the upper layer.

» To do this, head to the filter tab on the top, yes that's right, not the color tab for once. Once in this filter tab, click on blur and then select the gaussian blur [**Image D**]. This adds weight to the neighboring pixels in the blur and is where the glow for our neon lines will come from.

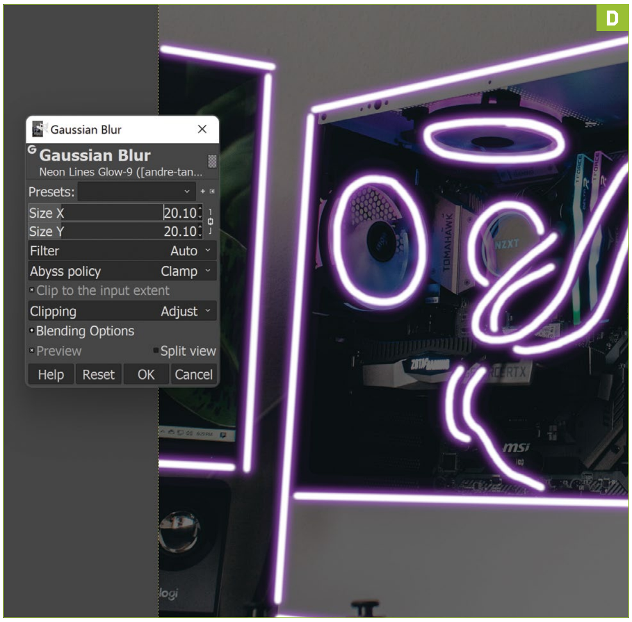
» Every image will be different, so play around by increasing and decreasing the X&Y sliders—you will see a live preview of how your image will look. Equally, you can go back to your original image and darken it again to create a greater contrast.

## 5

### LEARNING YOUR LINES

To complete our artwork, we are going to add some extra lines on some other items in the background. Of course, this is optional, but we wanted to add some glow to the leaves behind the PC. Not to detract from the PC, our main focal point, we decreased the size of our neon lines. We then repeated the whole process and just like magic, we were finished.

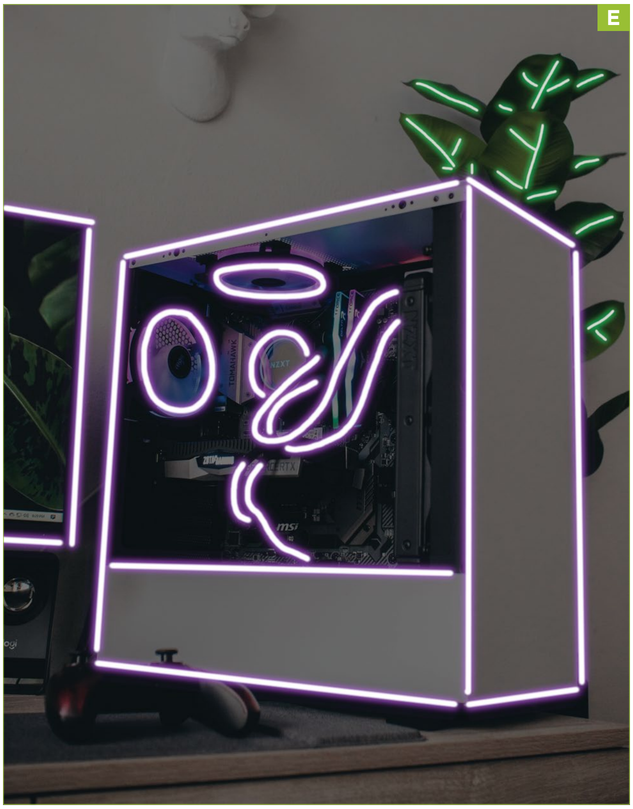
» This process isn't difficult, it takes time to figure out what you want to draw and how to emphasize the main subject. Once that is done, you can apply the glow effect for an eye-catching image [**Image E**]. You can transfer this skill to many different images, the rough effect adds a playful nature and also draws your eye to the most important part of the photo. ⏻



D

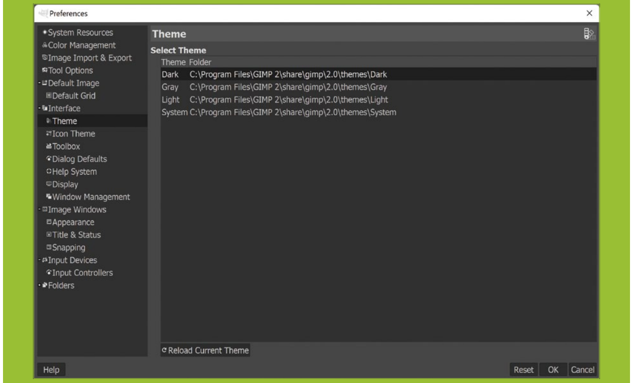
Gaussian Blur

**Gaussian Blur**
Neon Lines Glow-9 ([andre-tan...
Presets:
Size X 20.10
Size Y 20.10
Filter Auto
Abyss policy Clamp
☒ Clip to the input extent
Clipping Adjust
Blending Options
☒ Preview
☐ Split view



E

## GIMP PREFERENCES



Preferences

**Theme**

**Select Theme**

| Theme | Folder |
|---|---|
| Dark | C:\Program Files\GIMP 2\share\gimp\2.0\themes\Dark |
| Gray | C:\Program Files\GIMP 2\share\gimp\2.0\themes\Gray |
| Light | C:\Program Files\GIMP 2\share\gimp\2.0\themes\Light |
| System | C:\Program Files\GIMP 2\share\gimp\2.0\themes\System |

To get comfortable with a photo manipulation program, it's sometimes worth playing around in the settings to get your workstation exactly how you'd like it. Themes are an important part of this and switching between a dark/light mode can make a big difference to your productivity.

To do this in GIMP, head to edit, then preferences to open up the pop-up window. Here, you can tweak a variety of different settings to get GIMP looking the way you want. One important option is icon sizes, as this can alter from display to display, and if they are either too big or too small by default you can change that here. Also as we mentioned, you can change the theme from dark to light or vice versa. This can be useful if you are working through the night to get some work done—and, yes, we've all been there.

# LAB NOTES

**GUY COCKER**, EDITOR-IN-CHIEF

# HDR10+ PC gaming is coming

## Samsung goes big on gaming

**IF YOU'VE NEVER** been to a television manufacturer briefing, consider yourself lucky. They spend hours trying to sell features you don't need, running flattering demonstrations against rival panels, and bigging up those picture processing modes we all turn off as soon as we unbox the TV.

I recently went to an event hosted by Samsung, which began with some flogging of the 8K dead horse—8K displays account for just 0.15 percent of TV sales worldwide (see News, page 9). Thankfully, it soon moved on to something people do care about—gaming, and specifically PC gaming. There was a demo of futuristic racer *Redout* using Samsung's own HDR10+ standard, thanks to beta drivers provided by Nvidia. Like Dolby Vision, HDR10+ allows content makers to add dynamic metadata to the picture and, as our colleagues at *What Hi-Fi?* found, this makes the resulting image punchier, deeper, and more dynamic. Unlike Dolby Vision, HDR10+ is a royalty-free open format created by Samsung, and while it sells more televisions worldwide than any other manufacturer, Panasonic and Philips have also adopted the format.

Nvidia's new drivers allow game developers to perform source-based tone mapping, meaning they can take full advantage of a display's HDR capability. The *Redout* demo looked spectacular, although as Samsung noted, game developers will have to learn how to take advantage of HDR10+, meaning adoption could be slow at first. However, it will work with existing GPUs and be compatible with variable refresh rate standards, such as G-SYNC. There is further to go with the tech, as HDR10+ is still limited by the format's 10-bit color format compared to Dolby Vision's 12-bit, but it's an impressive step forward.

**Samsung's Gaming Hub, launching this summer, is a big deal for the manufacturer.**

Samsung also showed off its new gaming hub that will arrive this summer. A big part of this is cloud gaming integration with Stadia, Nvidia GeForce NOW, and Utomik. Samsung showed an impressive *Cyberpunk 2077* demo highlighting the improved 100ms latency and 120Hz processing on its latest screens. TV manufacturers see PC gamers as an important market, and we'll be featuring more on couch-based gaming in *Maximum PC* shortly.

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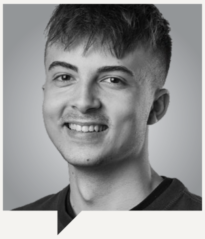


## SAM LEWIS

**Staff Writer**

As I'm sure you're aware, the team here at *Maximum PC* are absolute tech fanatics. We live and breathe any and all tech, whether it's new, old, exciting, quirky, or revolutionary.

However, there does come a time when you have to shut the lid on your laptop and log off for a bit. Luckily for me, that was in the form of a long-awaited holiday to the Greek island of Kos. When I go on holiday, I'm the complete opposite though, I like to distance myself from anything with as much as a battery inside of it and shut off from the world.

Saying that, I still brought my MacBook with me to watch some Netflix and Amazon Prime at night in the hotel as the local TV stations weren't doing it for me. Also, I still use a MacBook from time to time, so I'm sorry Team Windows for cheating on you.

Anyway, using a VPN was a necessity and made it easy to get access to the usual home comforts I'd watch. Plus, the added privacy through a VPN, specifically ExpressVPN, is always a must for me when using public Wi-Fi so I can't travel without one. When I first arrived in Kos, I struggled to get onto the internet so I used a trusty website to force me onto the landing page. If you are ever in the same boat, type in 'neverssl.com' into the search bar and this should force you to the public Wi-Fi's sign-in page. Hopefully, this tip helps a little for when you're next on the move.

© SAMSUNG

# Editor's Pick: Checking out ROG Citadel XV

Product placement in games? It's more likely than you think

**MARKETING THROUGH** games has become commonplace; in-game advertising is worth billions of dollars, as sports brands vie to have products featured in games played by millions of fans. But making an entire game from scratch to serve as a digital ad for your product?

These so-called 'advergames' have been around since the 1980s, with the release of *Tapper*, an arcade game sponsored by brewer Anheuser-Busch to promote their Budweiser product line. Players took control of a bartender tasked with delivering cold glasses of lager to impatient bar patrons.

Food and drink are a common theme in the advergaming world, with brands such as Pepsi, Burger King, Domino's Pizza, and Chex cereal all involved during the late 90s and early 2000s. Some were fun to play, with Domino's *Yo! Noid* platformer for the NES proving popular enough to get a fan-made freeware sequel 27 years later.

Even the US Military wanted in, releasing the *America's Army* series from 2002 to 2007 to boost the recruitment of young people. Making a game isn't easy and it's no wonder that advergames declined from 2010, as the process of making games became ever more demanding.

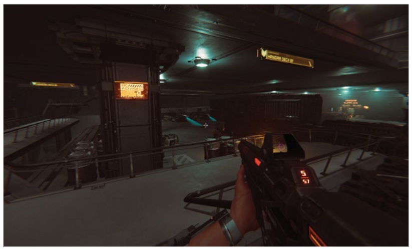
That hasn't stopped Asus from trying. *ROG Citadel XV* is a first-person shooter set in a floating cyberpunk city crammed with Republic of Gamers product placement. Asus released the game at the beginning of 2021 and has been steadily expanding it with new content and new product ads. The primary purpose of *Citadel XV* is to show off all the cool ROG hardware coming soon. You can peruse a virtual display room and check out the latest laptop releases with a 3D viewer. It could have been done in a web browser, but it's a novel way to browse the products.

The game doesn't cost a dime, much like how old advergames were free inside cereal boxes, so we didn't have high expectations. Still, there's a surprising amount on offer here, from drone-shooting missions to a pinball minigame and DLC that offers parkour assault courses.

Unfortunately, the whole thing runs like ass. Textures look flat, bugs are common, framerates are choppy, and many objects don't even register bullet impacts. The wall-running and grappling mechanics are fun, but the guns handle like bricks. There are worse ways to explore the new ROG product line, but I came away from Citadel XV feeling underwhelmed, even if the new ROG Flow X16 looks awesome.

Time may prove otherwise, but I don't think we'll see other manufacturers jumping on this bandwagon. Advergames should have died out in the early 2000s, along with flared jeans and Coldplay. Still, there's potential for games to serve a similar purpose; in a world where physical gaming and hardware expos are on the decline, could 'marketing simulators' such as the excellent *Devolverland Expo* from 2020 be the next frontier? **–CG**

$FREE, rog.asus.com



**Shoot robots to look at a new laptop? No way!**

© ASUS, WARNER BROS, LASTPASS

## Reviewed…

**74** MSI RX 6950 XT Gaming X Trio

**76** Geekom Mini IT8

**78** Lenovo Legion S7

**80** BenQ Mobiuz EX2710R

**82** MSI MPG Artymis 273CQRX-QD

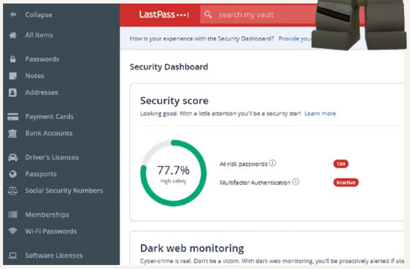
**84** HP Chromebook x2 11

**87** B&O Beoplay Portal

**88** NZXT Function

**89** NZXT Lift

**90** Lego Star Wars: The Skywalker Saga



How is your experience with the Security Dashboard? Provide you

Security Dashboard

Security score

Looking good. With a little attention you'll be a security star! Learn more

Dark web monitoring

Cyber-crime is real. Don't be a victim. With dark web monitoring, you'll be proactively alerted if site

**92** LastPass vs. Bitwarden

# MSI RX 6950 XT Gaming X Trio

## Cranking the GDDR6 dial all the way up to 18Gbps

**LAST MONTH,** we got Nvidia's new halo GPU, the RTX 3090 Ti. This month, AMD tries to respond with an upgraded RX 6950 XT—though we're using the term 'upgraded' loosely here. Fundamentally, the RX 6950 XT uses the same Navi 21 GPU we've had for around 18 months and, since the RX 6900 XT was fully enabled with 80 CUs, the only improvements come via increased clockspeeds. As with the RTX 3090 Ti, higher clocks also mean increased power limits and the MSI Gaming X Trio we received for review takes things even further.

We reviewed ASRock's heavily-overclocked RX 6900 XT Formula in our January issue and one of our complaints was that, for all the beefed-up cooling, factory overclock, and increased power consumption, the card was stuck with the same old 16Gbps GDDR6 memory. Considering even the lowly RX 6500 XT now makes use of faster 18Gbps memory, something previously only seen in the limited availability RX 6900 XT liquid-cooled card, it's no surprise that AMD is using the same 18Gbps memory on its refreshed 6000-series lineup.

The reference model RX 6950 XT comes with a 335W TBP (Typical Board Power) and a 2100MHz Game Clock. That's only 85MHz higher than the 6900 XT's Game Clock, but the MSI card comes equipped with triple 8-pin power connectors and gooses the clock speed quite a bit higher. For example, we measured average GPU clocks of 2545MHz while gaming, admittedly with an average power use of 420W. MSI's stated power rating is 340W, but perhaps it was only talking about power for the GPU rather than the entire card because it clearly went far beyond that mark.

### PUSH FOR PERFORMANCE

There's a balance between power and performance, and pushing for every last MHz can cause a big drop in efficiency. AMD didn't completely toss efficiency out the window with its reference RX 6950 XT, but its partners are free to do so, and MSI lands at the higher end of the power spectrum. The good news is that the 18Gbps memory gives the 6950 12.5 percent more bandwidth, which should help performance scale a bit better than factory overclocked 6900 XT cards.

Overall, the MSI card beat AMD's reference RX 6900 XT by more than ten percent in our 4K ultra testing, and it came in nearly ten percent faster at 1440p ultra as well. Gains at 1080p were far more muted, but we don't think most people will buy a card like this for 1080p gaming—unless it's in a heavily ray-traced game. Speaking of which, some of the DXR games we tested showed even bigger gains, thanks to GPU clocks that were over 20 percent higher than the base model 6900 XT.

Looking at the competition, the RX 6950 XT gets the overall crown going up against Nvidia's slightly more expensive RTX 3080 Ti, but it's much slower in games that use heavy ray-tracing effects. Whether or not you care about such things, much like the 3090 Ti, this refresh feels a bit late to the party. Early rumors are starting to show up regarding AMD's upcoming RDNA 3 architecture, which we expect to arrive before the end of the year. It's likely to provide a substantial boost to overall performance, and maybe even close the gap with Nvidia's GPUs in ray tracing games.

Even AMD fans will find little reason to upgrade to the slightly faster RX 6950 XT, assuming they already nabbed an RX 6900 XT sometime over the past two years. Sure, the price difference is only about $100 but as GPU prices continue to drop we finally have at least a bit of hope that the next generation cards won't end up horribly overpriced. The Radeon RX 6950 XT can legitimately claim to be the fastest AMD gaming GPU created so far, but it's not likely to retain that title into 2023 when we might see cards that cost half as much giving it some stiff competition. **–JARRED WALTON**

### BENCHMARKS

| | RX 6950 XT | RTX 3090 Ti | RX 6900 XT | RTX 3080 Ti |
|---|---|---|---|---|
| **10 Game Average** | 104 / 63 | **108** / **70** | 95 / 56 | 98 / 61 |
| **Borderlands 3** | **144** / 78 | 138 / **80** | 131 / 70 | 118 / 68 |
| **Control (DXR)** | 53 / 25 | **79** / **40** | 47 / 22 | 69 / 34 |
| **Cyberpunk 2077 (DXR)** | 29 / 13 | **50** / **25** | 25 / 11 | 44 / 21 |
| **Far Cry 6** | **150** / **94** | 140 / 91 | 141 / 86 | 130 / 82 |
| **Flight Simulator** | 82 / 55 | **87** / **70** | 77 / 49 | 84 / 59 |
| **Forza Horizon 5** | **136** / **98** | 115 / 88 | 130 / 91 | 107 / 80 |
| **Horizon Zero Dawn** | **170** / 93 | 162 / **102** | 160 / 85 | 150 / 89 |
| **Minecraft (DXR)** | 37 / 18 | **69** / **35** | 31 / 15 | 62 / 31 |
| **Red Dead Redemption 2** | 122 / 84 | **133** / **94** | 113 / 77 | 116 / 81 |
| **Redemption** | **121** / 69 | 109 / **71** | 98 / 58 | 98 / 63 |

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x 16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 2560x1440 / 3840x2160 ultra, with ray tracing enabled in Control, Cyberpunk, and Minecraft.

**VERDICT**
**7**

**MSI RX 6950 XT Gaming X Trio**

**+ UPGRADES** Fastest AMD GPU; relatively affordable; doesn't need 450W.

**− REFRESHES** Minor speed gains; weak DXR performance; RDNA 3 is coming.

$1,199, www.MSI.com

### SPECIFICATIONS

| | |
|---|---|
| **Architecture** | Navi 21 |
| **Lithography** | TSMC N7 |
| **Boost Clock** | 2629 MHz |
| **GPU Cores** | 5120 |
| **Memory** | 16GB GDDR6 |
| **TFLOPS FP32** | 26.9 |
| **Bandwidth** | 576GBps |
| **TDP** | 340W |
| **Connectors** | HDMI 2.1, 3x DisplayPort 1.4 |

AMD's refresh of Big Navi boosts the power limit and clock speeds to stretch performance to new heights.

This Mini PC can
handle simple
office tasks.

# Geekom Mini IT8

## Is this dinky desktop PC a viable laptop alternative?

**WE HAVE TO ADMIT** that, here at *Maximum PC*, we welcome products with the word 'mini' in their name. Whether that's down to the quirky nature and sheer novelty value of diminutive devices, or whether it's the prospect of small pieces of tech that take up little desktop real estate, we always have a soft spot for compact products. Just large enough to fit in the palm of your hand, Geekom's Mini IT8 PC clearly fits into this bracket.

There are some decent specs on offer—the version we have on test is the top-of-the-line model, which provides larger storage capacity and increased RAM over the other models in the lineup. With plenty of creative potential for some unique setups, including as an unusual laptop replacement, the Mini IT8 should make an interesting machine.

Although the compact size is its most obvious characteristic, the machine is incredibly versatile. In the box, there's a mounting kit that can be secured onto the back of a monitor, for example. If you're after a minimal setup. The Geekom Mini IT8 could easily be mounted underneath a desk and hidden out of the way for a sleek look. As it isn't visually groundbreaking, and certainly not a liquid-cooled show machine, it makes sense to hide it away.

Regardless of how you choose to set your Geekom up, it's an all-black design with the 'Geekom' branding on top. The front of the device features a USB Type-C (data only), a USB 3.2 Gen 2 Type-A, a headphone jack, and a power button. That's a positive selection of ports although one more USB Type-A port would be handy, to allow you to connect a mouse and keyboard from the front. However, it's hardly a stretch to connect it to the back of the device.

The rear side features two USB 3.2 Gen 2 Type-A ports, HDMI, USB Type-C (data & display), LAN, Mini DisplayPort, and a charging port. For such a compact device, it still has all the connectivity you'd hope for, and you can always connect a USB hub if you need extra ports. Don't forget the SD card slot on the side, which is a great addition for photographers and videographers who need to transfer files quickly after a shoot.

So then, what is this mini PC for? The one thing it is not pretending to be is a gaming rig. Our benchmark results show that the Geekom Mini IT8 isn't capable of running games at max settings. We tested titles such as *Ghost Recon: Wildlands* at low/medium settings and the Mini IT8 struggled to achieve anything higher than 20fps at 1080p. Without a dedicated graphics card, it's not worth trying—the integrated Intel Iris Plus 655 graphics just aren't cut out for it—but that's not what this machine is trying to achieve.

However, this humble device is more than enough for a handy day-to-day work machine. One of its main benefits is that it comes pre-installed with Windows 11. With compatibility issues on a range of similarly priced devices, it's good to see this OS working well on the Geekom, even though it isn't packing a recent CPU. Instead, it has the 8th generation Intel i5-8259U processor onboard, which will get most people's daily tasks done with ease.

With four cores and eight threads, you can get a max turbo frequency of 3.8GHz from the IT8, which is pleasantly surprising and means that office work, such as basic spreadsheets or Word documents, can be processed with ease. Our model has the larger 16GB of Kingston DDR4 RAM, which helps. Talking of which, you can connect this machine up to four screens so, if you're a multitasking procrastinator or a financial analyst, this will be right up your street.

At just shy of $500, what you get here is a compact but fairly capable hand-sized portable PC that can easily be disconnected from your setup and moved around. Although it is an extremely small device, unfortunately it will never have the same functionality that a laptop and its dedicated screen can offer. However, Geekom's Mini IT8 is a handy device for work-oriented tasks and has upgradable storage and RAM, which is a lot easier to change than on a laptop or traditional tower PC. It also gets special points for being so easy to tuck away behind a monitor for the all-in-one look. Ultimately, the Geekom Minit IT8 is a reliable daily workstation at a decent price tag, and would pair well with a sleek minimalist desktop aesthetic. **–SAM LEWIS**

**VERDICT 7**

**Geekom Mini IT8**

**+ DOES THE JOB** Great size and shape; plenty of ports; potential to upgrade.

**− NEEDS MORE OOMPH** Gaming is a no-no; similarly priced laptops offer more; has old CPU.

$449, www.geekompc.com

### SPECIFICATIONS

| | |
|---|---|
| **CPU** | Intel Core i5-8259U |
| **GPU** | Intel Iris Plus Graphics 655 |
| **Memory** | Kingston 16GB DDR4 @2400 MHz |
| **Ports** | 3x USB 3.2 Gen 2, 2x USB Type-C, Mini DisplayPort, HDMI, Gigabit Ethernet, SD card reader, 3.5mm audio jack. |
| **Connectivity** | Bluetooth 4.2, Intel AC-7265, Wi-Fi 5.0 |
| **Dimensions** | 4.6 x 4.4 x 1.8-inches |
| **Weight** | 1.24lbs |

### BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| **Cinebench R15 Multi (Index)** | 904 | 586 (-35%) |
| **CrystalDisk QD32 Sequential Read (MB/s)** | 493 | 2,545 (416%) |
| **CrystalDisk QD32 Sequential Write (MB/s)** | 312 | 1,214 (289%) |
| **3DMark: Fire Strike Ultra (Index)** | 1,233 | 1,846 (50%) |
| **Rise of the Tomb Raider (fps)** | 6 | 8 (33%) |
| **Total War: Warhammer II (fps)** | 6 | 9 (50%) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i3-10100, 8GB (2x4GB) Corsair Vengence LPX DDR4 @3000 and a 240GB Kingston A400 2.5-inch SSD. All game tests are performed at 1080p at the highest graphical profile.

The S7's RGB keyboard is one of the most vibrant we've seen in a laptop.

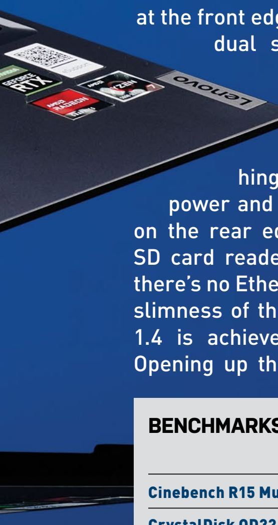
# Lenovo Legion S7

## Steely but slender

**LENOVO'S LAPTOP RANGE** just keeps getting better. Expanding on the existing selection of Legion 5 and 7 models comes the S7, shorthand for 'Slim 7'. And it is pretty slim, measuring in at barely more than half an inch thick with the lid closed and weighing just over 4lbs, a far cry from the average 15.5-inch gaming laptop.

Priced at $1,770 (although that's just the model we were sent for review; both cheaper and more expensive SKUs are available, with a customization page on Lenovo's website allowing you to build your perfect S7), it sits just above the budget gaming laptop sphere, and it's not hard to see why. Immediately upon unboxing and booting up the S7, it's clear that this is a product designed with serious quality in mind.

The outer casing is sleek brushed metal with a Legion logo printed on the lid and an underbelly that tapers upwards at the front edges to create space for the dual speaker system beneath. The entire assembly feels exceptionally robust, with thick rubber feet and a firm hinge on the screen. The power and USB-A ports are situated on the rear edge, with USB-Cs and an SD card reader on the sides. However, there's no Ethernet connection due to the slimness of the body, while DisplayPort 1.4 is achieved via the USB-C ports. Opening up the laptop reveals a bright 1440p LCD screen and an even brighter RGB keyboard, one of the most vibrant we've seen on a laptop.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The display is available in configurations from 1080p up to 4K, although the 4K version is limited to a 60Hz refresh rate. Our 1440p iteration runs at a speedy 165Hz, ideal for the high framerates demanded by eSports games but can easily be swapped to a battery-saving 60Hz mode with a hotkey shortcut. The screen offers good maximum brightness and excellent color reproduction at 99.3 percent sRGB.

That RGB keyboard is a genuine pleasure to type on and it's no slouch for gaming either. While there isn't a huge amount of travel due to the S7's slim form, actuation feels responsive and these keys aren't 'spongy' in the way some laptop keyboards can be. Holding down the Function key illuminates only the keys with matching shortcuts, making it even more intuitive. The trackpad is wide and offers a firm click, with reliable palm rejection when using a separate mouse.

Internally, the Legion S7 we were sent packs all the hardware you'd expect from a sensibly-priced midrange gaming laptop. The CPU is AMD's Ryzen 7 5800H, a solid choice of mobile processor with eight cores and a boost clock of up to 4.4GHz. For graphics, we've got the slimmer Max-Q variant of the Nvidia GeForce RTX 3060 featuring 6GB of video memory. The 16GB of RAM is split into one soldered and one non-soldered SODIMM sticks, so it's partially upgradable. The same goes for the SSD, which is available in 512GB, 1TB, and 2TB configurations.

The RTX 3060 is well-suited for gaming at 1080p, which makes the broad range of available displays an odd choice, especially since you can't upgrade the GPU (a version with an RTX 3050 Ti is available, but we'd avoid that). Still, FHD gaming on the S7 is fantastic, with smooth framerates at maximum settings. Kicking things up to 1440p demands some settings be lowered to remain above 60fps, but it's an option in free-to-play titles and strategy games.

Ray-tracing, on the other hand, isn't really viable. The 3060 doesn't have the processing power to handle Ultra RTX presets, with lighting, shadows, and reflections causing a serious hit to framerates. Otherwise, CPU performance is strong, with decent scores in Cinebench R15 and the CPU-bound *Total War* benchmark. The S7 ran warm during testing, most likely due to its metal chassis and cramped internals, but the fans remained quiet under load.

Battery life is above average for a typically power-hungry gaming laptop. The S7 can comfortably handle two or three hours of video editing at 50 percent brightness before it needs charging, and the 230W power supply fills the battery from empty in under two hours. If you're willing to drop the brightness further or use Eco mode, battery life can be stretched even further, which is what we'd suggest for people on-the-go.

We were impressed with the Legion S7—it's a high-quality product with good performance and a sensible price tag. It's one of the best 1080p gaming laptops on the market right now, and a much lighter option than the excellent albeit much beefier Legion 5i Pro we reviewed in our June issue. **–CHRISTIAN GUYTON**

**VERDICT**

**9**

**Lenovo Legion S7**

**⊞ ZERO CALORIES** Amazing build quality; good 1080p gaming performance for the price; decent battery life.

**⊟ FULL FAT** Thermal performance could be better; needs more ports.

$1,770, lenovo.com

### BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| **Cinebench R15 Multi (Index)** | 1,030 | 1,942 (89%) |
| **CrystalDisk QD32 Sequential Read (MB/s)** | 3,374 | 3,605 (7%) |
| **CrystalDisk QD32 Sequential Write (MB/s)** | 2,530 | 3,075 (22%) |
| **3DMark Fire Strike (Index)** | 13,610 | 15,949 (17%) |
| **Rise of the Tomb Raider (fps)** | 92 | 112 (22%) |
| **Total War: Warhammer II (fps)** | 62 | 88 (42%) |
| **Tom Clancy's Ghost Recon: Wildlands (fps)** | 49 | 61 (24%) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Acer Predator Triton 500, with an Intel Core i7-8750H, Nvidia GeForce RTX 2060 Max-Q, and 16GB of DDR4-2666. All game tests are performed at 1080p at the highest graphical profile.

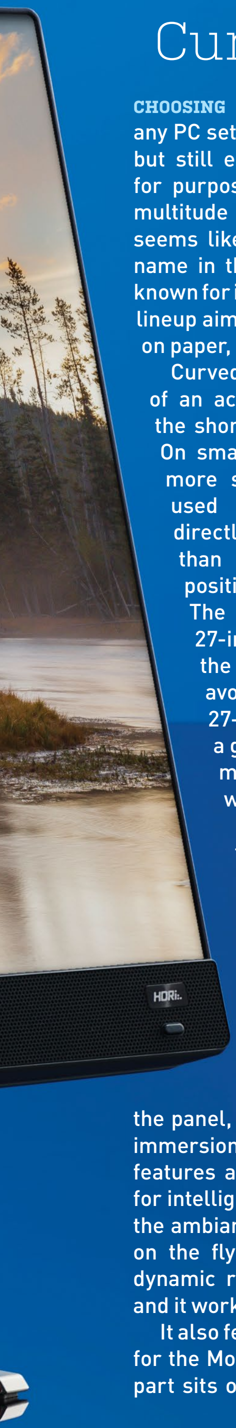
### SPECIFICATIONS

| | |
|---|---|
| **CPU** | AMD Ryzen 7 5800H |
| **Graphics** | Nvidia GeForce RTX 3060 Max-Q |
| **RAM** | 16GB SODIMM DDR4 @ 3200MHz |
| **Screen** | 15.6-inch 1080p LCD IPS screen @ 165Hz |
| **Storage** | 512GB M.2 NVMe SSD |
| **Ports** | 3.5mm Combo Audio Jack,<br>2x USB 3.2 Gen 2 Type-A,<br>2x USB 3.2 Gen 2 Type-C,<br>SD card reader |
| **Connectivity** | WiFi 6, Bluetooth 5.1 |
| **Weight** | 4.19lbs |
| **Size** | 14.0 x 9.9 x 0.63-inches |

The BenQ Mobiuz EX2710R monitor in all its curvy glory.

# BenQ Mobiuz EX2710R

## Curved, VA, and a high refresh rate... we're hooked



**CHOOSING A MONITOR** is a huge part of any PC setup. You could spend a fortune, but still end up with something not fit for purpose. So a monitor that ticks a multitude of boxes at a decent price tag seems like a no-brainer. BenQ is a big name in the screen game, but it's less known for its gaming monitors. Its Mobiuz lineup aims to change that and, certainly on paper, the EX2710R looks promising.

Curved monitors are something of an acquired taste, especially after the short-lived history of curved TVs. On smaller displays, a curve makes more sense as it will typically be used by just one person sitting directly in front of the screen, rather than the whole family jostling to position themselves on the sofa. The EX2710R features a 1000R 27-inch curved panel that has just the right amount of curvature to avoid awkward angles. In fact, 27-inches is a happy medium for a gaming monitor, though we are more accustomed to an ultra-wide setup at this size.

This monitor has a sturdy two-piece stand to keep it upright and a vertical adjustment that allows it to swivel 15° and tilt 5° so you can get the perfect angle. If anything, we'd prefer the stand to be monochrome and to lose the red, but that's just nitpicking.

Around the top and sides of the panel, thin bezels help with in-game immersion, while the bottom bezel features an HDRi sensor. The 'i' stands for intelligence, as this sensor measures the ambiance of your room. HDRi adapts on the fly to provide a more effective dynamic range based on your lighting, and it works effectively on this monitor.

It also features one part of the speaker for the Mobiuz EX2710R, while the other part sits on the back. Sound output is a plus point—many screens either offer terrible tinny tweeters or none at all, so it's nice to see some here. Sure, it won't blow your socks off, but it's a useful backup if you haven't got headphones or an external speaker connected. There are also preset EQs built into the menu for FPS, cinema, racing games, sports games, and pop/live music, which helps to get the sound you want. This is controlled via the ibundled remote, another added bonus that you don't tend to get with monitors. All PC users know the struggle of changing settings with the buttons underneath the screen, so we welcome the inclusion of a remote here.

Round the back of the EX2710R, there is an average selection of ports; two HDMI 2.0 ports, one Display Port 1.4, a USB Type-B (upstream) and USB Type-A 3.0 (downstream), and a 3.5mm auxiliary headphone jack. It would have been nice to see an extra DP port here, as this is commonly the best way to connect PCs, as well as USB Type-C because, well, it's 2022. There's also a cover in the box to hide the cabling, which is a nice touch for those who like to keep a clean desk setup.

The monitor's attention to detail is superb, with plenty of options to tweak the screen to your liking. After only a few minutes of calibrating, we were up and running. As a 1440p VA panel, the color depth is rich and the contrast is strong. Using the HDRi mode gives you the benefits of HDR, only adapted on the fly to the conditions in your room. Instead of your eyes having to adjust to the changing light in your room throughout the day, the monitor makes the adaptations automatically, which, in theory, results in less eye strain. After testing the HDRi mode for a few days, we can confirm that it does alter the balance and works effectively to maintain the characteristics of the high dynamic range mode.

As for the VA panel, these typically deliver deeper blacks and stronger contrasts than IPS displays but the latter offers better viewing angles. On this monitor, viewing angles aren't too much of an issue due to the curvature of the screen, particularly as you are likely to be seated directly in front of it.

In addition to the color accuracy and deep blacks, the screen also has a 1ms response time and a refresh rate of 165Hz. There are monitors with higher refresh rates, but 165Hz is plenty for the majority of gamers. It ticks plenty of boxes for the $550 price, with color accuracy and rich details good enough for productivity plus a snappy refresh rate for gaming. Features like the auto HDRi mode, remote control and cable tidy make for an even more well-rounded package. If you're after a dependable gaming monitor, the BenQ Mobiuz EX2710R will definitely fit the bill. **–SAM LEWIS**

**VERDICT**
**9**

**BenQ Mobiuz EX2710R**

**+ POSITIVE** 1000R curved screen; high refresh rate; rich detailed panel; HDRi support.

**− NEGATIVE** No USB-C; only one DisplayPort.

$550, www.benq.com

### SPECIFICATIONS

| | |
|---|---|
| **Panel size** | 27-inch |
| **Panel type** | VA |
| **Resolution** | 2560 x 1440 |
| **Brightness** | 300nits (peak HDR 400nits) |
| **Contrast** | 3000:1 |
| **Pixel response** | 1ms |
| **Color gamut** | 90% P3 |
| **Refresh rate** | 165Hz |
| **Connectivity** | 2x HDMI 2.0,<br>1x DisplayPort 1.4,<br>USB Type-B (upstream),<br>USB Type-A 3.0 (downstream),<br>3.5mm auxiliary jack. |

# MSI MPG Artymis 273CQRX-QD

## MSI's gaming monitor also aims to please creative types

**TRADITION DICTATES** that PC manufacturers sell different products for different purposes. Creative type? Get a Macbook Pro. Gamer? Try the Razer Blade 15. However, as we've all become multi-hyphenates—gamers who livestream, influencers who photo edit, office workers who side-hustle—we've needed machines that can adapt and keep up. MSI recognizes this trend, as its MPG Artymis 273CQRX-QD is a gaming monitor that pulls double-duty as a creative display. That means it boasts gamer-friendly features such as a high refresh rate and adaptive sync, but also has 95 percent DCI-P3 color space coverage and USB-C display support.

Often when companies try to please everyone, they end up appealing to no one, but that thankfully isn't the case here. Yes, there are compromises, but these are mostly on the creative side. The VA panel doesn't quite have the color and contrast uniformity of an IPS display, the curve isn't ideal if you're a video editor, and for some inexplicable reason, the USB-C port's power delivery is only 15W, which means it can't charge a laptop while you're working.

However, if you primarily want a monitor for gaming with some creativity on the side, then the MSI is well worth checking out. The panel's resolution hits the 1440p sweet spot, its refresh rate is a whopping 240Hz, and it supports AMD's FreeSync Premium Pro. There are plenty of inputs, including DisplayPort, USB-C, and two HDMI, meaning you can have a desktop, laptop, and multiple consoles all connected at the same time.

MSI has also included some excellent quality of life features for gamers. A hook emerges from the right of the screen so you can hang your headphones when you've finished playing, and there's a mouse bungee to keep the cable out of the way when you're strafing the undead in *Doom Eternal*. The monitor also has built-in features to improve your skills, such as a crosshair that always contrasts with whatever's on screen, and night vision to brighten up shadows so you can more easily see enemies approaching.

As you'd expect, it also supports MSI's Mystic Light RGB standard, with a light panel and logo on the rear that can be customized via software. We also liked that the monitor's firmware can be upgraded over USB and that it supports KVM, so you can use a single keyboard and mouse across multiple systems.

While this may be a VA panel, it's one of the best examples of the technology that we've seen. MSI claims 100 percent sRGB, 93 percent Adobe RGB, and 95 percent DCI-P3 color space coverage, and we can report that MSI's Quantum Dot technology does an excellent job of color reproduction. The 400 nits peak brightness is par for the course these days, but the high 3000:1 contrast ratio fares much better.

Viewing angles are good for VA, and while it's still best to be sat dead center given the curve, contrast and color remain decent even off-axis.

The specs on this monitor are ideal for most gamers. The 1440p resolution is a big upgrade over 1080p without taxing your GPU so heavily that you'll have to invest in a $1,000+ GPU, and the standard 16:9 format will also keep video editors happy. There are higher refresh rates available but, realistically, 240Hz is more than enough for all but the most competitive eSports players, while the 1ms response time makes this a highly responsive display. Given all this, it's an excellent gaming monitor for anyone with a mid-range PC. MSI's hardware choices result in a screen that has excellent performance without breaking the bank.

If you're primarily a gamer who occasionally does a bit of creative work, this is definitely a monitor to have on your shortlist. But if you work as a creative full-time, you'll probably want to look elsewhere. **–GUY COCKER**

VERDICT
8

**MSI MPG Artymis 273CQRX-QD**

**+ CURVE APPEAL** High refresh rate; lots of inputs; wide color gamut.

**− FALLING FLAT** Contrast and color shift; low 15W power delivery; no G-Sync.

$500, www.msi.com

### SPECIFICATIONS

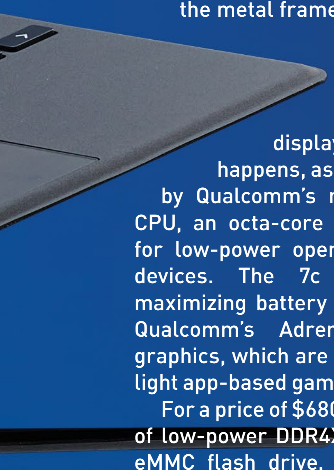
| | |
|---|---|
| **Panel size** | 27-inch |
| **Panel type** | VA |
| **Resolution** | 2,560 x 1,440 |
| **Brightness** | 400cd/m2 |
| **Contrast** | 3000:1 |
| **Pixel response** | 1ms |
| **Color coverage** | 95% DCI-P3 |
| **Refresh rate** | 240Hz |
| **Vesa** | 100mm x 100mm |
| **Inputs** | DisplayPort 1.2a, HDMI 2.0b x 2, USB-C with 15W PD |
| **Other** | HDR400, Audio Out, FreeSync Premium Pro |

MSI's monitor is great for gamers and pretty good for creative types too.

The HP Chromebook x2 11 is a laptop/tablet hybrid that's good for light gaming.

# HP Chromebook x2 11

## Magnetic personality



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**'CHROMEBOOK' HAS** become an increasingly nebulous term as of late. Where it once simply referred to a cheap, basic laptop running ChromeOS, the definition now encompasses a broad variety of more powerful productivity laptops, tablets, and 2-in-1s. The x2 11 from HP occupies the latter category, a laptop alternative that leverages a detachable keyboard to serve as the perfect hybrid platform.

The first thing we noticed about the x2 11 is its display; this dinky hybrid tablet boasts an 11-inch 1440p LED screen with a maximum 400 nits of brightness and 100 percent sRGB color reproduction. It's bright and vibrant, comfortably beating the 1080p displays of other Chromebooks despite its smaller size. It's an edge-to-edge glass panel, but it sits just inside the metal frame of the tablet and so it shouldn't shatter if you drop the x2 on its edge.

Behind that display is where the magic happens, as the x2 11 is powered by Qualcomm's new Snapdragon 7c CPU, an octa-core processor designed for low-power operation in ChromeOS devices. The 7c is optimized for maximizing battery life, and also packs Qualcomm's Adreno 618 integrated graphics, which are able to handle some light app-based gaming.

For a price of $680, our model has 8GB of low-power DDR4X RAM and a 128GB eMMC flash drive, the latter of which would usually be a deal-breaker for its slow transfer speed and limited capacity. Thankfully, ChromeOS is centered around cloud-based storage, so you won't have to worry about photos and documents cluttering up your local drive.

The 'hybrid' aspect of the x2 comes into play with its detachable keyboard and kickstand, which snap magnetically to the bottom edge and rear of the tablet respectively. The kickstand is rather unusual; a large rectangle, hinged in the center, that covers the entire back of the tablet with a square hole for the rear camera. Once it's attached, you can bend it to whatever angle you want, which is a pleasant change from the fixed-position kickstands on some hybrid laptops.

The keyboard is decent, with a matte finish that doesn't pick up grubby fingerprints and a firm actuation on each key that makes for a satisfying typing experience. It's best used with the x2 set up in 'laptop mode' on a solid surface, otherwise, it has a tendency to flop around. Unfortunately, the trackpad doesn't match this quality. It feels a little inaccurate and the click is rather flimsy, especially towards the upper center of the pad. Removing the kickstand and keyboard for the true tablet experience reduces the overall weight by almost half, making it easy to handle.

Speaking of connecting stuff, this Chromebook has just two ports: a pair of USB-C 3.1 inputs on the left-hand side, either of which can be used for charging the tablet. Above these ports sit the volume control buttons, which have a nice clean click. The same can't be said for the power button, which feels weirdly springy and doesn't always register a press. The built-in speakers, which fire from thin slots on either side of the display, are decidedly feeble with little to no bass and a tinny quality to higher-pitched sounds.

In terms of performance, the x2 does well for productivity tasks. We opened a total of 16 tabs in Chrome before we noticed any significant UI slowdown, which should be just fine for the average user. The Snapdragon 7c actually performed slightly better in Geekbench 5 than it did in the Acer Chromebook Spin 513 that we featured a few issues back, which was impressive.

Gaming is viable (sort of)—ChromeOS now includes full support for the Google Play Store, which has a wealth of app games. Basic 2D games, such as *Cultist Simulator* and *Crying Suns*, ran fine and even some 3D games ran pretty well too—*Pokemon Unite* maintained a solid 55fps, even during hectic teamfights.

As advertised, the x2's battery life is excellent, surpassing the 11-hour duration advertised by HP for basic media playing and web browsing with audio muted. That's all-day use on a single charge, which is what most Chromebook buyers expect. There isn't much a Chrome device needs that the x2 11 doesn't offer—it's a small object of desire that's excellent for productivity, web browsing and gaming. **–CHRISTIAN GUYTON**

**VERDICT**

**8**

**HP Chromebook x2 11**

**+ FLEXIBLE** Great portable productivity tool; display is fantastic; good battery life.

**− STIFF** Poor speakers; flimsy trackpad; weird power button.

$680, www.hp.com

**SPECIFICATIONS**

| | |
|---|---|
| **OS** | ChromeOS |
| **CPU** | Qualcomm Snapdragon 7c |
| **Graphics** | Qualcomm Adreno 618 |
| **RAM** | 8GB LPDDR4x SDRAM |
| **Storage** | 11-inch 1440p LED IPS screen |
| **Display** | 128GB eMMC Flash Drive |
| **Ports** | 2x USB 3.1 Gen 1 Type-C |
| **Connectivity** | Wi-Fi 5, Bluetooth 5 |
| **Battery** | 32WHrs 2-cell Li-ion |
| **Weight** | 1.23lbs (2.27lbs with keyboard cover and kickstand) |
| **Size** | 9.9 x 7.0 x 0.3-inches |

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# Bang & Olufsen Beoplay Portal

## Looks, performance, and the sound to back it up?

**IT'S FAIR TO SAY** there are levels to a good pair of headphones—you can have some that deliver a wide and detailed soundstage, yet feel like they were put together in a shed. Essentially, what you need is a good balance between sound, style, comfort, and features.

Bang & Olufsen is a brand that seems to strike the right balance across its whole lineup. The Beoplay Portal headphones are aimed at two markets, tackling gaming as well as traditional headphone usage. At just under $500, is this the all-in-one pair of cans you need?

First impressions matter and it's often the initial thoughts that can set the tone for the device. Fortunately, this works in the Beoplay Portals' favor, as they are a nice-looking pair of headphones. Our review sample, which comes in the 'grey mist' colorway, certainly offers the premium quality that the brand is known for. Paired with the shiny grooved ear cups, this color choice is our favorite of the bunch, just ahead of the navy and black options in terms of style.

Design-wise, B&O has opted to maintain the traditional premium headphone style that the company has become known for. That it hasn't chosen to go down a route of appealing to the gamer aesthetic and has opted for a more neutral design helps make the device more attractive to wear on the go.

In terms of comfort, the headset is light enough for all-day use, but it doesn't feel cheap, which is what you'd hope for at this price. The Portals are finished in soft lambskin leather with a bamboo knit headband. Pair the materials and the Portal's lightweight frame together and you can wear these for a while without feeling the tension on your ears or head.

Thankfully, features are also a big selling point of these wireless earphones. They come in two variants, our version is the PC/PlayStation option but you also can get an Xbox model. In the box, there's a USB-C wireless adapter included along with a USB-A converter too. This makes for a seamless wired connection, but it's not the only choice. Bluetooth 5.0 is available, with a dedicated button on the left ear. On the right, there are options for a 3.5mm auxiliary and a USB-C wired connection. That's plenty of choices and makes this a highly versatile pair of cans.

### TOUCH-SENSITIVE SLIDERS

On the left ear cup, there's a touch-sensitive slider that alters the active noise-cancellation level. It's easy to get used to, although we prefer physical sliders. On the other side, there's a slider to control the volume. For the controls on the faces of the ear cup, you double-press to play/pause on the left, and double-press to skip tracks on the right side. When gaming, these presets change, and double-tapping the left side changes the gaming equalizer, while double-tapping the right side mutes your microphone.

Talking of which, the Portals do a decent job at picking up your voice while trying to soften the background noise. Considering it's an internal microphone and not a physical boom arm, it works well, but for the price, we might have expected a little more. When using these headphones, it's best to pair them with a smartphone, so you can download and use the Bang & Olufsen app. This is where the majority of your customization and preset controls are, and you can update the headphones and set them up through the app before diving into a listening session. It may take time initially, but it's worth it to get the best sound possible.

The Beoplay Portals don't disappoint on the sound quality, with a warm and detailed sound package. On first listen, we tweaked the equalizer to add a little bass and that gave us a great and well-rounded sound. The lows are rich and the mids to highs offer the full sound you expect for this sort of price tag. You can listen to these cans for long periods without the sound being too overpowering. As for gaming, again with the right adjustments, the sound is detailed and crisp enough to pick out key elements in the game. The strong low end helps deliver the atmospheric ambiance you'd want from immersive titles like *Resident Evil Village*. It performs both of its functions well, and given the lack of competition in the gaming/lifestyle space, that's exactly what you want. If you have the budget and you're looking for a premium two-in-one device, this ticks both of the boxes. **–SAM LEWIS**

**VERDICT 9**

**Bang & Olufsen Beoplay Portal (for PC or PlayStation)**

**+ CREAM OF THE CROP** Premium detailed sound; plenty of features; beautiful design.

**− CURDLING** Pricey pair of cans; mid-tier microphone.

$500, www.bang-olufsen.com

### SPECIFICATIONS

| | |
|---|---|
| **Driver type** | 40mm Electro-dynamic Neodymium driver |
| **Frequency response** | 20Hz-22,000Hz |
| **Connectivity** | 3.5mm Auxiliary, Bluetooth 5.1, Wireless Dongle connectivity (USB A/C) |
| **Compatibility** | PC, PlayStation, Mobile |
| **Battery life** | Up to 19 hours w/ wireless gaming, Bluetooth and ANC.<br>Up to 42 hours w/ Bluetooth and ANC |
| **Design style** | Closed back |
| **Weight** | 0.61lbs |

# NZXT Function

## Typing into the peripheral mainframe

**RENOWNED CASE GIANT** NZXT has been attempting to gain a foothold in the wider peripheral market. In our last issue (June 2022), we tested the company's Capsule microphone, which proved to be a good start for expansion into areas where its name is less well-known. The company's latest products are a keyboard and mouse combo, so it seems like a good opportunity to test both out in this issue, starting with the Function keyboard here, the MiniTKL variant, which is the smallest of the bunch. NZXT has also released a full-sized and a tenkeyless (TKL) option, so should you go for NZXT's first keyboard or opt for a name with more experience in this field?

If compact peripherals appeal to you then this MiniTKL form should be right up your street. A standard TKL board is usually compact, but NZXT's MiniTKL format fits those same features into an even smaller shell. It essentially gets rid of the empty spacing around the TKL board and compresses all the keys together. It's not quite as small as some 60 percent boards, but is noticeably different from regular TKL keyboards. Let's just say it won't take up much space on your desktop.

As for the design, we have the matte black option, with matte white being the other choice available. If you're after a more specific aesthetic, you can choose to customize the board using the NZXT BLD (build) program, however, these two standard offerings are in line with NZXT's brand image and pair perfectly with the company's cases, which is good if your case is visible on your desktop.

There are no sharp unusual shapes or gamer-inspired designs here, but that's not a bad thing. Although this keyboard reaches out to the gaming market, it could easily fit into an office-based or productivity environment. The minimal design could be viewed as boring but with the per-key RGB backlighting, it's easy to fit into any setting. Unfortunately, this lighting isn't the brightest, but does disperse evenly throughout the board. If you want to play around with this, the RGB lighting for the Function is adjustable within NZXT's CAM application.

To the left side of the keyboard, there are media controls that are sometimes missing on compact boards. These include a rubberized volume wheel, mute, Windows lock button, and keyboard brightness cycle button. Ergonomically, it makes sense to have these on the left-hand side as, more than likely, your right hand will be using the mouse—though left-handed mouse users may not agree.

Underneath, there are two adjustable levels of kickstands to ensure a comfortable angle for typing. One thing that's missing from this MiniTKL board is the wrist rest, so you'll need to roll your own. The other two keyboards in the lineup come with wrist rests, albeit they are more expensive, but it's a shame one was not offered on this more compact version.

### KEY TO SUCCESS

What about the actual keys on this NZXT Function? Well, the caps themselves aren't too impressive. Out of the box, they're ABS, which feel cheap and are a nightmare for fingerprints. Using NZXT's BLD program, you can opt for PBT caps, but these come at a higher price. The switches underneath are more impressive and are hot-swappable with a key tool that's included if you want to customize this further. Gateron red switches come pre-installed on this board and require little pressure to type on. For long durations of typing, it's a comfortable switch to use without too much audible feedback. Yet, as this is a gamer-focused keyboard, more tactile feedback and louder switches would perhaps be more suitable. The upside is that, being a hot-swappable keyboard, you can change the keys and switches to suit your personal tastes. However, the NZXT BLD program can soon get expensive, and you could end up paying north of $200 for a customised keyboard.

Although it's a well-made keyboard, there are better alternatives on the market for a similar price that don't necessarily need to be customized. We'd recommend upgrading to the PBT caps as these are much better than the ABS ones, but you can't help but feel they should come as standard. This MiniTKL variant is a great looking board, but it can feel cramped after long durations.

If you're after a productivity board or one for long periods of gaming, we'd recommend the larger boards with a wrist rest. The Function isn't a bad board and is certainly a decent first attempt at cracking the keyboard market, it just requires a fair amount of customization to get it to a reasonable level. **–SAM LEWIS**

**VERDICT**
**6**

**NZXT Function Keyboard**

+ **FUNCTIONAL** Easy customization; removable cable; ergonomic media buttons.

− **DYSFUNCTIONAL** No wrist rest; slightly cramped; no USB pass-through; cheap ABS caps.

$120, www.nzxt.com

**SPECIFICATIONS**

| | |
|---|---|
| **Switches** | Hot-swappable Gateron Linear Red |
| **Switch Durability** | 50 million+ presses |
| **Design Style** | MiniTKL |
| **Connection** | USB-C to USB Type-A |
| **Wrist-rest** | N/A |
| **Weight** | 1.58lbs |

# NZXT Lift

## Clicking into the peripheral mainframe

**AS PART OF THE** company's expansion into the wider peripherals market, NZXT has released a mouse and keyboard combo, with the Function keyboard (reviewed opposite) alongside this Lift mouse. The NZXT Lift is a budget mouse, so maybe the brand is pinning its hopes on value-for-money peripherals attracting an audience looking to get into gaming. There is, of course, plenty of choice when it comes to gaming mice as it's a highly competitive market, so is this NZXT offering worthy of your time?

At first glance, the mouse is in keeping with the design of the Function keyboard. Finished in a matte material, it could pass in a more conventional office setting. Though an ambidextrous design, it still favors right-handed users, as there are two programmable side buttons on the left side for right-handed users' thumbs. One thing to mention here is that the mouse has quite a low profile and there isn't much room to rest your thumb on the side of the mouse without hitting these buttons. It's unlikely that you'll accidentally actuate them, but for comfort purposes, it's not ideal.

On the other hand, the mouse is generally a comfortable place to rest your hand, thanks to its matte plastic finish. Our review sample is the standard white version, though the Lift also comes in a black matte design. Through NZXT's website, you can customize the accent color on the mouse to add a splash of character to the design, with a choice of blue, cyan, purple, red, or yellow to spice things up. If you opt for the NZXT combo of the Function and Lift, you could create an interesting setup theme with the customizability on offer.

To help match your theme, the Lift has a subtle RGB underglow which is controllable in the NZXT CAM software. There are six available buttons with mappable availability within the program. We've already mentioned the two buttons on the side, but you also get a DPI/profile button, which sits below the scroll wheel. This wheel feels great to use, as it's covered in a dotted rubber that grips well and gives you plenty of control over scrolling.

Press the DPI/profile button to cycle through levels of 400, 900, 1800, and 3600dpi. You get visual confirmation of which DPI you have selected via the RGB under-glow on the lift. This is also configurable in increments of 100dpi and you can pick a custom color to add to these settings over on the CAM software. Long-pressing this button lets you choose between four different profiles that can be adjusted in the software.

On the whole, the mouse has some nice design cues—the matte finish isn't slippery and there's no rubberized grip on this peripheral. It's a lightweight mouse too, which could be one of its downfalls—it seems NZXT has favored performance over build quality here as the mouse has some plastic creaking and feels a little on the cheap side.

But it's in the performance where the Lift is really elevated to a higher plane. There are three PTFE feet, one at the top, one around the sensor, and one on the bottom of the mouse that all help the device glide gracefully over your desktop. Aside from the Lift's weight, the cable also helps the performance. It's a 2m Paracord cable that delivers low drag and, together, the result is a mouse that replicates some of that feeling of freedom you get with a wireless mouse.

In terms of the sensor, it's a popular optical PixArt 3389. It feels responsive, snappy, and accurate—exactly what you'd want from a mouse but a pleasant surprise at this price. As for the switches for the left and right clicks, the Lift uses Omron mechanical switches. They are quick to actuate and have a tactile spring to them, which makes it comfortable for use for both work and gaming.

For a mouse, the NZXT Lift isn't exactly groundbreaking, nor does it offer anything new that isn't already on the market, yet this is a solid first attempt by the brand. For under $50, you get a good-performing, lightweight mouse, with NZXT opting for performance over general build quality. It's not poor quality by any means, it just creaks under the slightest pressure, feels a little cheap in places, and doesn't feature any rubberized grips other than on the scroll wheel. But if performance is paramount and you're on a budget, then this is a worthy choice. **–SAM LEWIS**

**VERDICT 7**

**NZXT Lift Mouse**

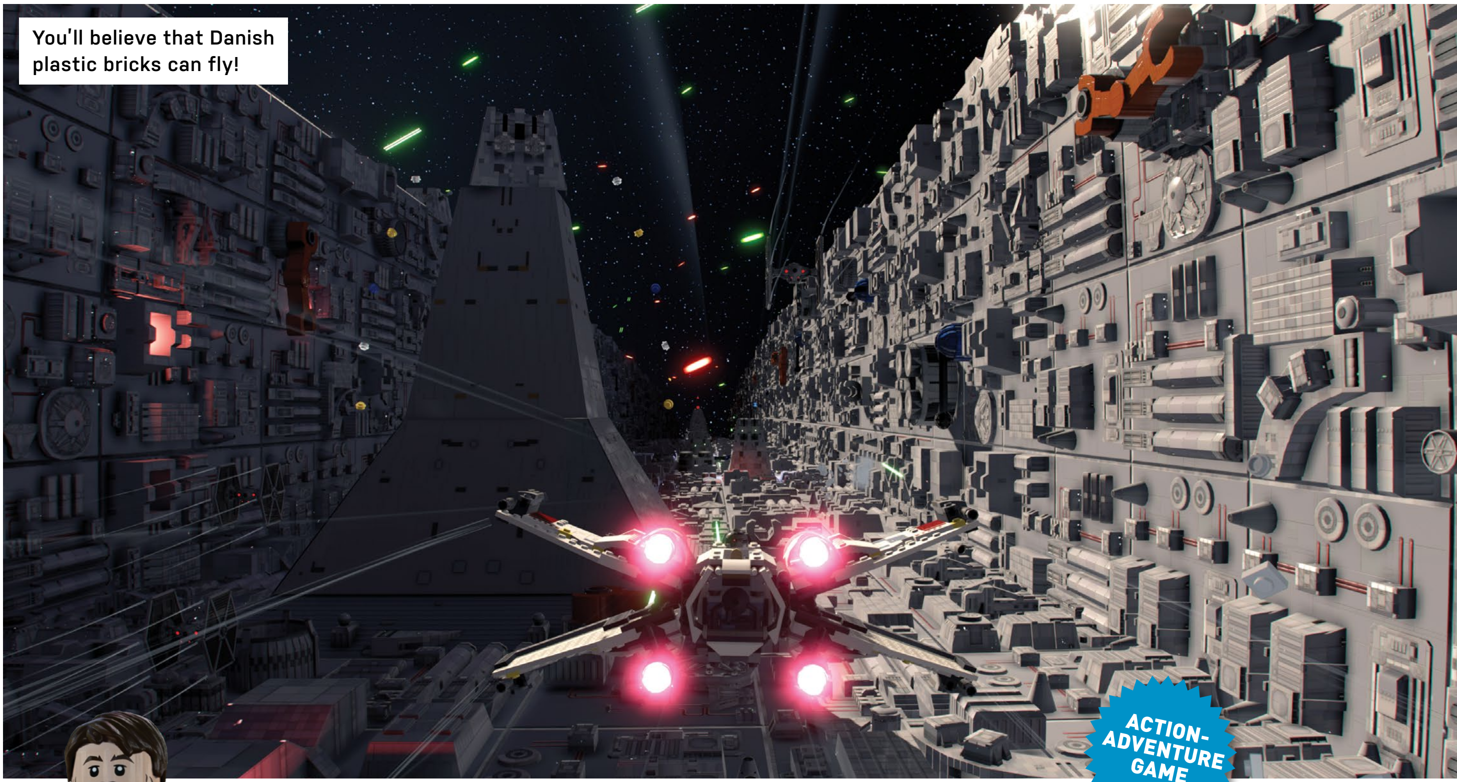
➕ **MOOD RISER** Zippy performance; lightweight; good value for money.

➖ **MOOD DOWNER** Cheap-feeling plastic; tight thumb room.

$50, www.nzxt.com

### SPECIFICATIONS

| | |
|---|---|
| **Sensor** | PixArt 3389 Optical |
| **Max sensitivity** | 16,000dpi |
| **Polling Rate** | 500Hz-1,000Hz (adjustable) |
| **Mouse switches** | Omron mechanical |
| **Weight** | 0.14lbs |



You'll believe that Danish plastic bricks can fly!

ACTION-ADVENTURE GAME

# Lego Star Wars: The Skywalker Saga

## A chip off the old block

**THE LEGO SERIES** has been hard to avoid since the first *Star Wars* game in 2005. Also including *Indiana Jones, Batman, Harry Potter,* Marvel, DC, Pirates... Lego has cherry-picked the jewels in the crown of modern entertainment, converted them into plastic blocks, and now returns to where it all began.

This isn't a franchise you'd expect to give up any new details or meanings after over 40 years but in Lego guise, it gains the charm Lucas always stretched for with his droids, porgs, and jizz music, but never quite grasped. The little moments are everywhere, from the beginning where a space traffic stop leads to the hiding of some suspicious Evil Plans, while the Death Star levels show what stormtroopers do on their days off—and we weren't expecting tai chi.

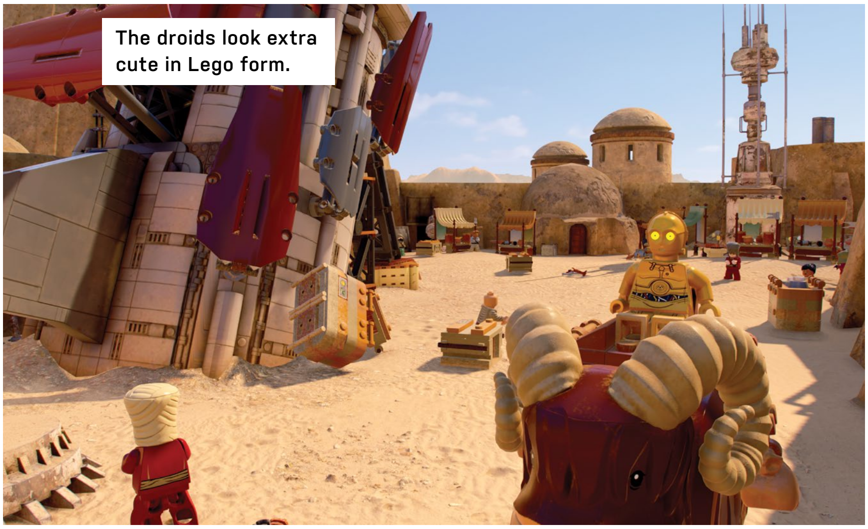
Rather than choosing to simply boost the resolution and port the older games into a new engine, *The Skywalker Saga* contains fresh takes on familiar events, turning the linear levels of the past into open-world romps in which you explore to discover who to talk to and where to go next. All nine of the movies are here, split into five levels each, and even the ones we don't like to talk about involving Gungans are rendered a lot of fun simply through the inclusion of one feature: local co-op.

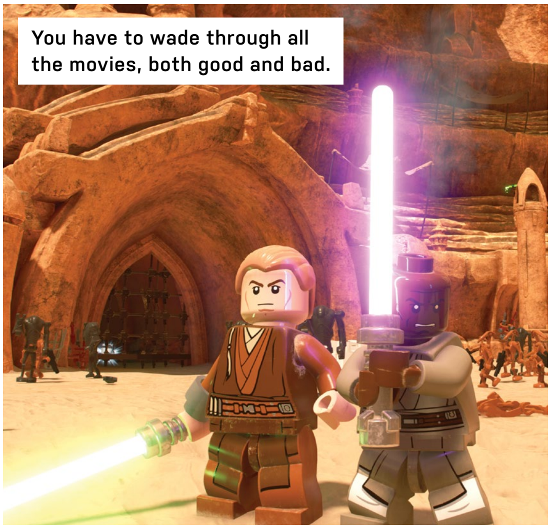
Hook your PC up to a big TV facing a sofa, and sit there with two controllers and a kid or partner for some simply awesome gaming times. We tried it on a five-year-old test subject, for whom it marked only their second contact with videogames, and were amazed as she turned Princess Leia into a punching machine, taking stormtroopers apart close-up in a style sadly not seen in the movies. Later, as Obi-Wan, the same tactics saw battle droids chopped into tiny pieces with a lightsaber. There's a combo system behind all of this, launching your character into the air while raining blows down on your target.

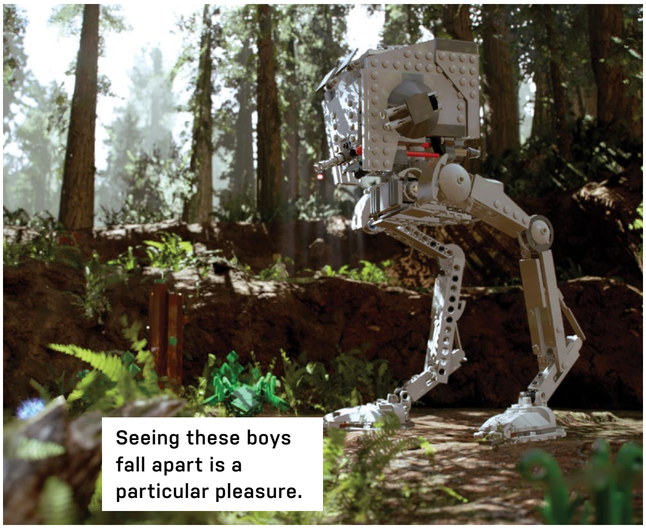
Even the blasters get some love, as *The Skywalker Saga* takes Han and Co in a third-person shooter direction, with aimed shots meaning you'll now rival the stormtroopers for accuracy. Building remains part of the game, with the need to create switches out of nearby blocks before you pull them, or stack handy platforms to access higher areas. There are, of course, certain objects that can only be interacted with by particular characters—Han is good with anything mechanical, Rey builds gliders and traps, while only Jar-Jar can play the Gungan dancing game that lets you take a transport to the surface, blasting giant fish on the way. The previously underused protocol droids also come into their own when faced with an NPC who speaks a language you can't understand.

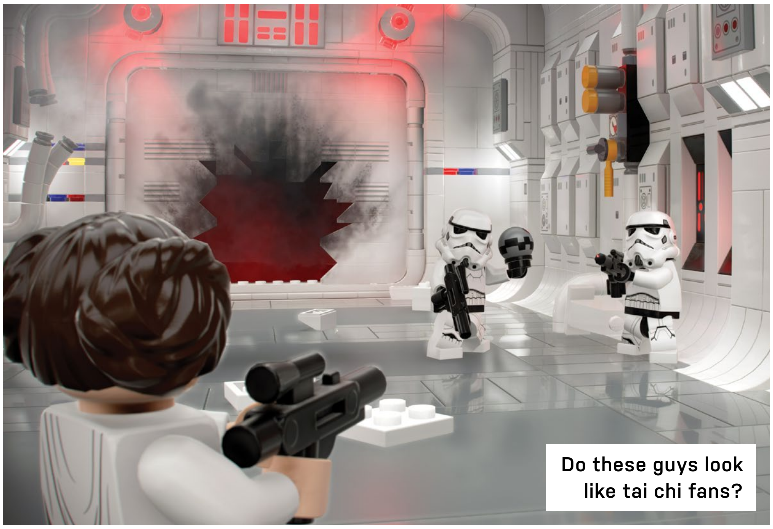
In between levels, you're punted to orbit, where you can fly around shooting rocks and discovering side missions before deciding to carry on with the story. There's a progression system tied to the collection of kyber crystals, with 1,100 or so hidden around the various levels that can be used for upgrades to walking speed or gigantic space lasers, and more than 350 characters to unlock along the

© WARNER BROS


The droids look extra cute in Lego form.


You have to wade through all the movies, both good and bad.


Seeing these boys fall apart is a particular pleasure.


Do these guys look like tai chi fans?

way. It's a huge hunt, and going back to previous levels with new characters just to winkle another one out from its hiding place can double the length of the game. Nothing here is particularly difficult, but solving the puzzles that release the crystals is a fun challenge.

## TO BOLDLY GO

Along with being the new boarding point to the Lego games for those who haven't played before, what *The Skywalker Saga* brings to the series is nostalgia and fan service. You can play the trilogies in any order, though you always have to start with the first film (yep, even *The Phantom Menace*), but this just means *A New Hope*, the most iconic of them all, is in easy reach. Its new twist on the 'Han shot first' controversy takes its lead from *The Naked Gun*, and while each episode follows the plot of the film, they're not afraid to throw in extras to poke a little fun at a po-faced moment or enhance a puzzle sequence.

It also takes advantage of the simple geometry of its block-based aesthetic to put on some really remarkable sights. Battles as the sun goes down, the light catching the sharp edges of fighter ships, or the shadows among the trees of Endor as AT-STs stomp about can rival the sights of other more realistic games. Of course, you get to fly a speeder under the legs of an AT-AT, and the trench run depicts a Lego set of such complexity we don't think we'd ever get it finished. Even the Gungans' underwater city is rendered and lit lovingly, turning it into the *Final Fantasy* conurbation that never was.

If we have one complaint, it's the way the game adapts its missions to its new more open world. We spent so much time following Luke around at walking pace that we began to lose interest in what he had to say. And trying to find the right character to talk to in a bustling city full of NPC figures can also be time-consuming. We also dislike that the split-screen presentation of co-op remains in splitscreen all the time, instead of merging the two views when the characters are close enough, something even *Lego Indiana Jones* on the Wii was able to manage.

Otherwise, this is an extremely polished production, filled with jokes and fan service, that will enthrall those unfamiliar with the material and provides a new angle on old events even for those who have played it all before. It's a game designed to be shared in the moment, rather than as a series of war stories after the fact, and the small amount of hassle involved in setting up a co-op session pays off handsomely in terms of added fun. **–IAN EVENDEN**

**VERDICT**
**8**

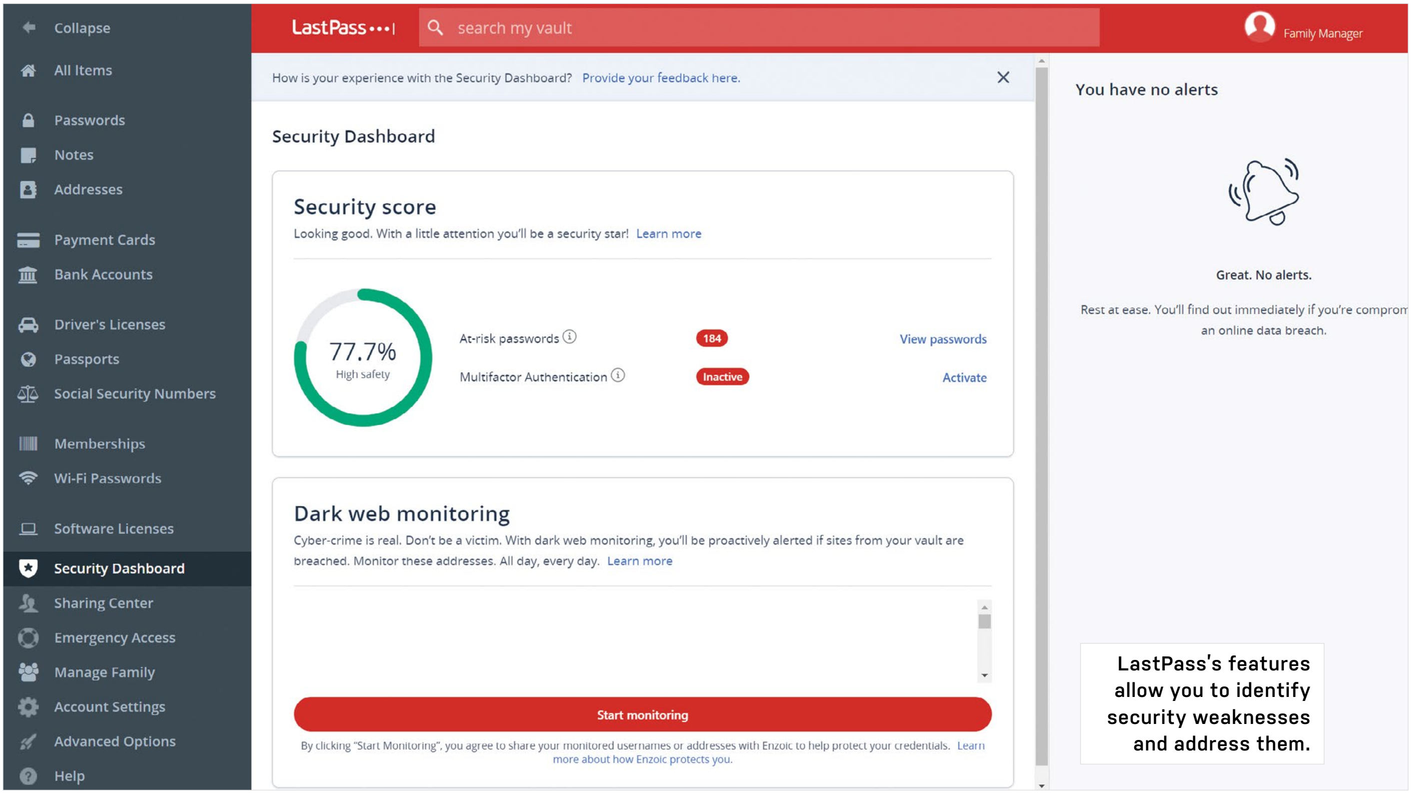
**Lego Star Wars: The Skywalker Saga**

**+ HAN CO-OP** Good-looking return to a galaxy far, far away.

**− HAN SOLO** Some missions are duds; can feel over too quickly in single player.

**RECOMMENDED SPECS** CPU, i5-6600 / Ryen 3 3100. RAM, 8GB.GPU, GTX 780 / R9 290.

$49, www.starwars.com/games-apps, E-rated



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|---|---|---|
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| Multifactor Authentication | Inactive | Activate |

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You have no alerts

Great. No alerts.

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an online data breach.

LastPass's features allow you to identify security weaknesses and address them.

# LastPass vs. Bitwarden

## Which password manager is better?

**WHILE THE WORLD'S** leading technology companies are finally vowing to put an end to passwords by using a smartphone-based PIN, fingerprint, or face unlock (see News, page 10), passwords remain essential for now. Google Chrome and Windows Credential Manager will perform the basics of remembering your passwords and suggesting secure logins, but that quickly becomes a problem if you frequently switch platforms or software. If you use more than one device, as most people do, then a password manager is the answer, as it works across platforms and syncs between devices. The result is that you never have to remember a password again, other than the one you use to access the password manager, of course.

Having had the password manager conversation with friends at dinner parties (yes, we are *that* person), we can already feel the eye rolls—and we get it. Moving to a password manager and then remembering to use it is a pain at first. But security is such an important part of your digital life that once you make the leap, you'll soon wonder how you managed without one.

On their most basic level, password managers do exactly what they say on the tin—they store and manage your passwords. But it's the extra bells and whistles that make them essential. They integrate with browsers like Chrome and operating systems, such as Android and iOS, and automatically fill in login information on sites and apps you've used before while suggesting new unique passwords for those you haven't. They can also be used to store sensitive information beyond just passwords, such as credit cards, ID information, and private notes.

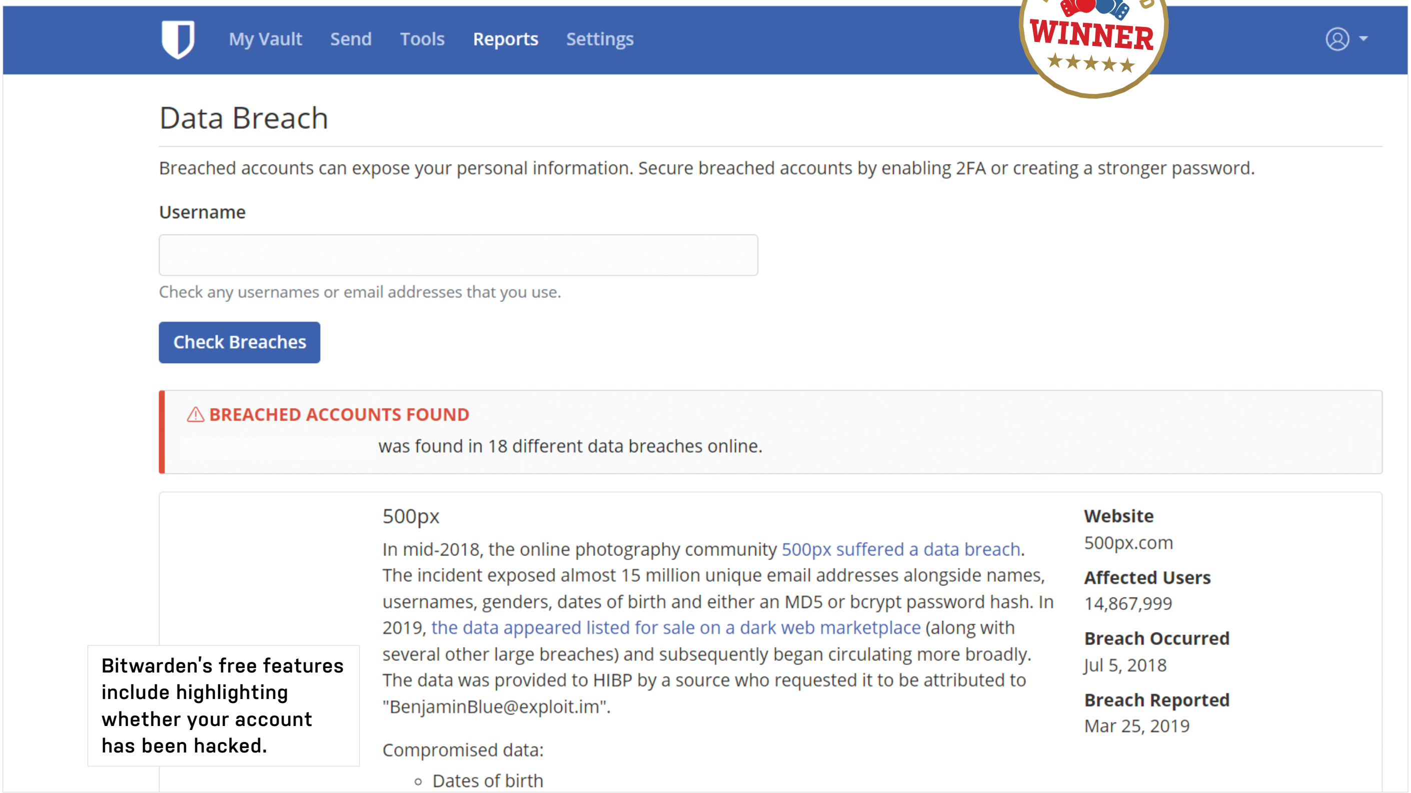
There are plenty of password managers to choose from and, although we only cover two here, we'd also recommend checking out NordPass pr 1Password if you're in the Nord ecosystem or a Mac user, respectively. Here, we focus on two of the most popular options: LastPass and Bitwarden.

Until last year, LastPass was the de facto choice for many because it was really good and also free. It's still really good, but sadly no longer free, as LastPass now charges users if they want to access their database on more than one type of device (free users can only do computers, or only do mobile devices), which makes it useless for most. LastPass Premium, which unlocks this feature and adds more features, is $36 per year (equivalent to $3 per month), while Families, which lets you share Premium features between up to six people, is $48 per year ($4 per month).

If a piece of software is well made and/or valuable, then it's definitely worth paying for, and LastPass is certainly both. But if all you need to do is securely store and access passwords across a variety of devices, Bitwarden will do that for you for free, which makes it an immediate winner for most. To justify paying out for LastPass Premium, you will need to take advantage of its advanced features, which include emergency access plus a security dashboard with dark web patrolling. There's also 1GB of encrypted file storage, but Sync.com offers that for free.

LastPass's security dashboard is worth deploying once or twice a year, as it will alert you to any passwords that may have been compromised, or any that are being duplicated across multiple services. Of course, the more you use a password manager, the more unique passwords you should end up creating, and the less duplication becomes an issue, but LastPass can also auto-change passwords on websites such as Facebook

© LASTPASS



Data Breach

Breached accounts can expose your personal information. Secure breached accounts by enabling 2FA or creating a stronger password.

Username

Check any usernames or email addresses that you use.

Check Breaches

⚠ BREACHED ACCOUNTS FOUND

was found in 18 different data breaches online.

500px

In mid-2018, the online photography community 500px suffered a data breach. The incident exposed almost 15 million unique email addresses alongside names, usernames, genders, dates of birth and either an MD5 or bcrypt password hash. In 2019, the data appeared listed for sale on a dark web marketplace (along with several other large breaches) and subsequently began circulating more broadly. The data was provided to HIBP by a source who requested it to be attributed to "BenjaminBlue@exploit.im".

Compromised data:

- Dates of birth

Website
500px.com
Affected Users
14,867,999
Breach Occurred
Jul 5, 2018
Breach Reported
Mar 25, 2019

Bitwarden's free features include highlighting whether your account has been hacked.

and Amazon just to add another layer of security. Emergency access is another modern-world essential, as it allows you to set access permission for certain contacts either immediately or after a period of time.

This means that, if the worst happens and you're in an accident or otherwise unable to access important information such as medical records, financial accounts, or anything else that unforeseen circumstances might require, your next of kin can obtain your details instead.

These are great features for LastPass, but the problem is Bitwarden also has equivalents in its premium offering, which is priced at a much more competitive rate. Bitwarden Premium is just $10 a year for an individual who wants emergency access and security reports, rather than the $36 annually for LastPass. Bitwarden Family, which again offers premium features to up to six users, is $40 compared to LastPass's $48 offering. All of this means that you're probably better off starting out with Bitwarden, which has a free offering with enough features for most people, while its premium features are cheaper if you need them at a later date.

So, is there any point in going for LastPass? As you'd hope from the premium price, it feels like a more premium product. The main difference is that there's more granularity to categories, with separate listings for bank accounts and payment cards, whereas Bitwarden only has cards. LastPass also has separate sections for Wi-Fi passwords, addresses, and memberships, basically, any information that you need securing, LastPass will do it. We also preferred LastPass's security reports, which break down how well you're doing overall and make it easy to address any potential issues.

Bitwarden, while more basic overall, still has its benefits. If you're a power user and would prefer to control where Bitwarden stores its information, then you can host it on your own network or server, which is free to do no matter what plan you're on. Its simplicity also makes it easier to use overall, as you can manually add banking details as a secure note in your banking login details, meaning it's all in one place. However, we found Bitwarden's Chrome plugin annoying to use, as it would freeze when typing in search terms, meaning it would miss letters and then not find the correct information.

Ultimately, these are two good password managers that nail the basics while offering some excellent features to justify their premium price tags. LastPass in particular is easy to use, while the organization freaks among you will love having your entire life's worth of private information to hand in an emergency. Once you have your passport information stored digitally in a secure vault, the idea of having to root around for your physical passport when booking a flight seems archaic.

As it stands though, we recommend you start with Bitwarden, whether you're new to the password manager game or you already have a password manager you're paying for without taking advantage of the advanced features. All of these password managers make it easy to export your data from one service to another, although do remember to encrypt the exported CSV or JSON files if possible, and properly delete the local file and your old vault when you're finished. – GUY COCKER

© BITWARDEN

**VERDICT** 8

**LastPass**

+ **FINAL FRONTIER** Easy-to-use; excellent categorisation; great security reports.

− **FINAL DESTINATION** Free version is limited to one type of device; premium features cheaper on Bitwarden; can't host on own server.

LastPass Free $free, LastPass Premium $36/year, LastPass Families $48/year
www.lastpass.com

**VERDICT** 9

**Bitwarden**

+ **BINARY SOLUTION** Free tier actually useful; premium tiers cost less than LastPass's equivalent; can host on your own server .

− **BYTE ME** Less easy to use than LastPass; fewer categories than needed; buggy Chrome plug-in.

Bitwarden Free $free, Bitwarden Premium $10/year, Bitwarden Families $40/year, www.bitwarden.com

# LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> SSD Firmware Woes
> Laptop Longevity
> Dead as a Drobo
> Sony Gaming Phone

## Not so solid crew

I just read your "So Solid Crew" feature in the May 2022 issue, and I thought I should respond with a buyer beware comment in terms of the Seagate Firecuda 530. As good as the drive is, the Seagate does have one serious chink in its armor, which is that Seagate has no utility for updating the firmware.

To do a firmware update, you must find and download the relevant .bin file from Seagate, then you had best know your way around PowerShell and be able to follow convoluted command line string instructions from Seagate. That issue alone makes the other vendors' options look much more appealing.

I did find some online posts indicating that people had successfully used the Seagate's Seatools firmware update to update their SSD firmware, but Seagate does not list that as a supported method.

I wish I'd known this before I splashed out for the Firecuda 530 a year and a half ago, as I would have picked a different drive that has a 21st-century method of firmware updating.

Despite being a pretty good drive overall, the Firecuda 530 only gets a score of six from me, due to its lousy software, and the fact that it's still expensive compared to the competition. **–B.J. Koho**

**EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:** Thanks so much for letting us know about your experience with this particular drive. It's evidence that no matter how thorough we are with our reviews, there's always more to find out about a product, some of which only becomes apparent when you've owned it for a while. I'm sorry we didn't mention this in our review, and I'm glad we have a chance to address it here.

I looked over the various user forums for this drive, and you appear to be correct in that the only way to update the Firecuda 530's firmware is via a Powershell interface that has a few hoops to jump through in terms of commands. I'm going to give *Maximum PC* readers the benefit of the doubt here and say that the majority of you should be able to work out how to do it. But the point is, you shouldn't have to, especially on such an expensive drive.

Your letter also sent me down a personal rabbit hole learning more about my own SSD and how to upgrade its firmware. I recently bought the 2TB Samsung 980 Pro with Heatsink also included in the roundup, removed the heatsink, and installed it into the Lenovo Legion 5i Pro I reviewed in the June 2022 issue (page 82).

Luckily, Samsung's drive has an excellent app called Magician, which updates the firmware with one click. Updating the firmware resulted in a 6 percent increase in read speed and a 51 percent increase in write speed—the latter is probably an anomaly, but it was well worth spending five minutes doing. Thanks again for the tip!

## Latest laptop love

I've been catching up on the "Gaming laptops suck" article by Jeremy Laird (February 2022, page 72). I'm still rocking my 2014 Toshiba QosmioX70 17-inch laptop. Admittedly, I've upgraded it a bit, adding an M.2 drive and running two additional SSD Drives (yes, this beast has an M.2 slot plus two further SATA III slots) and upgrading it to 32GB of memory.

It runs like a champ on Windows 10 and, being a software consultant, I've generated seven digits of revenue using this machine over the past eight years. I don't play the latest triple-A games on ultra settings, but that doesn't bother me. I haul around a machine that lets me run multiple virtual machines locally, and plays *Diablo III*, *Divinity: Original Sin 2*, and *Grim Dawn*—not bad for an eight-year-old machine!

It's just a shame that Toshiba doesn't make a modern version of it because I will eventually be in the market for a new one! **–B. Maciolek**

↘ submit your questions to: editor@maximumpc.com

**EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:** It appears you're a few issues behind, so you might not yet have gotten to the April 2022 issue, where I posted my own response to this article titled "Gaming laptops DON'T suck".

I don't have a laptop that's eight years old—which is pretty impressive—but I like to think my current machine will still be playing games a few years down the line, especially if, like you, I make a few upgrades here and there. I recently moved home and a month later, I still haven't set up my desktop PC, because my laptop is such a good machine for working and playing games.

The GPU in your PC is the GTX 770M, which would struggle with a lot of modern games, but as you say it's enough for some of the classics, as well as the less demanding modern games and free-to-play titles. The rest of the system is by no means cutting edge, but it's no slouch either, with a quad-core processor and 32GB of RAM, albeit slower DDR3L.

The real question is whether anyone out there is rocking an older gaming laptop? Let me know on the email below!

## NAS the way to go?

I have been a reader of your magazine for a while now but I'm yet to see any article regarding storage. More specifically, Network Attached Storage.

I am the virtualization SME for a rather large DIY store that loves the color orange and have been working remotely for over two years now. I've built out a new home office and a new PC and am now building an "Office" file and print server. I now find myself needing storage with redundancy. My current solution is a ten-year-old Drobo with 16TB of storage, backed up to the cloud via BackBlaze. It still works fine, however, the device is no longer supported by the vendor, and is very slow over USB. I'd love to know what else is out there, and what *Maximum PC* thinks about them. **–C. Kitchens**

**EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:** This isn't the only question we've had this month about NAS drives—see the Doctor's advice on page 14 about creating your own NAS. The short answer to rolling your own is that it's difficult to find power-efficient components right now, so pre-built is the way to go.

My personal experience is with Synology's systems, of which I use the DS918+. Even though it's nearly five years old, it works like a dream, has excellent ongoing support, and does everything you've asked of a networked storage device.

Synology's SHR RAID system makes it easy to chuck different drive sizes in the NAS (I even have a couple of 18TB drives in there, which aren't officially supported) and be safe in the knowledge that you're protected against single drive failure.

It also makes an efficient file server both locally and remotely, a print server (although I've not used this feature myself), plus mine runs scheduled backups to OneDrive overnight for extra peace of mind.

As the Doctor says though, there are other NAS vendors out there such as QNAP and Asustor, the former of which I met and was impressed by at this year's Consumer Electronics Show. We clearly need an updated NAS guide, so watch this space for something in a future issue!

## Ode to Sony

I saw your recent article on gaming phones (May 2022, page 70) and loved your thoughts. In fact, I love your magazine in general as I learn a lot about tech from it, even at the age of 77.

I suggest you look at the Sony Xperia 1 III or the recently-announced Xperia 1 IV. I have had every Sony phone they have released with a 4K screen, and they now boast 120Hz refresh rates as well. This might make a difference with games. I've found that Sony phones are not on the mainstream list and get overlooked a lot. **–R. Short**

**EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:** I've been a technology journalist for some time and like you have had experience with nearly every Sony Xperia phone over the years.

I will always remember being at the launch of the Xperia Play phone in 2011, known as the "PlayStation Phone", which seemed doomed from the off as you had to repurchase PlayStation games for the device, even if you already owned them on the console.

Thankfully, the Xperia line has improved a lot since then, and you're correct in saying they have some of the best displays and cameras on the market. I'm still not personally convinced you need a 4K display on a mobile, but there's no doubt how good content looks on Sony's flagships.

I don't know why Sony's phones don't seem to land with the consumer, but I suspect it's because the Japanese company doesn't spend anywhere near as much on marketing as Apple and Samsung do, plus the confusing nomenclature for their devices doesn't help. I appreciate the tips on gaming phones though—if anyone else has a recommendation for portable gaming, please let me know.

## Better late than never

In your Ultimate Games Preview (May 2022, page 36), you forgot to talk/laugh/cry about *Star Citizen*! WTF?

I'm sorry. I had to.

**–P. Kadron**

**EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:** For anyone not following the *Star Citizen* drama, it's an in-development game from Wing Commander director Chris Roberts that has seen a series of delays. So much so, that the developer said earlier this year that it will stop posting release projections which keep slipping and then upsetting fans.

It's almost a certainty in the gaming media that if you create a games preview feature as we did a couple of months ago, the minute you go to press, at least one of those games will get delayed or canceled. We just managed to catch *Suicide Squad: Kill The Justice League*, which got pushed to 2023 as we were closing the issue, but sure enough, two Bethesda games also slipped to 2023 in the form of *Starfield* and *Redfall*, both featured in our preview as 2022 releases.

There's been predictable uproar from fans who have been blaming Xbox head Phil Spencer in the fallout, but there are two things to bear in mind. One is that the punishing practice of crunch at the end of a game's development is something that needs to end. And the second is that a good game is better than a rushed game. And as our preview showed, there are plenty of other games coming our way to enjoy in 2022.

# THE BUILDS

THIS MONTH'S STREET PRICES...

## BUDGET

**WOW!** Our Intel system looks like a whole new PC. The only things staying the same are the SSD (the T-Force Cardea Graphene Z44L is still one of the best-value PCIe 4.0 drives) and the Corsair 4000D Airflow case, everything else is new. The budget Intel rig was lagging behind the AMD system with its i5-12400 chip and RTX 3050 GPU, so both have been upgraded. The CPU is now the i5-12600, which is closer to the Ryzen 5 5600X in terms of performance with a similar price, beating it in multi-core workloads and significantly in single-core performance.

The GPU has jumped up a rung in the Nvidia hierarchy with an RTX 3060 from Gigabyte, which sits beneath the RX 6600 XT in the AMD build in terms of performance. Despite the lower RRP of the 3060, the 6600 XT is currently the cheaper card to buy, with GeForce GPU prices falling slower than Radeon ones.

The Intel system also benefits from a new B660 motherboard and power supply, from Gigabyte and XPG respectively. These changes were made to mitigate the overall price hike created by upgrading our GPU; LGA-1700 motherboards are still expensive, with the new socket type not yet the norm amongst PC-builders. We haven't featured an XPG power supply in this section before, but these power bricks are as reliable as the best-known brands.

With the Kingston FURY memory back up to RRP, we've swapped out the Intel build's memory to keep the price down. In its place is the faithful Ripjaws V 16GB kit from G.Skill. The AMD build's only major change is a new motherboard, the MSI MAG B550 Tomahawk, at $114. The final change in the Intel rig is the hard drive, a shift mimicked by the other budget build and both midrange machines. It's a simple swap from Western Digital to Seagate, with the affordable Constellation ES HDD. It has a higher RPM but less cache memory than the WD Blue, but this isn't our primary storage, so shouldn't be an issue.

### AMD INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Corsair 4000D Airflow | $95 | |
| PSU | 550W Asus TUF Gaming 80+ Bronze | $56 | |
| Mobo | MSI MAG B550 Tomahawk AM4 **NEW** | $114 | |
| CPU | AMD Ryzen 5 5600X | $229 | |
| GPU | XFX Speedster SWIFT210 Radeon RX 6600 XT 8GB | $379 | $400 |
| RAM | 16GB (2 x 8GB) Corsair Vengeance LPX CL16 @ 3600MHz | $78 | |
| SSD | 500GB MSI Spatium M450 PCIe 4.0 M.2 SSD | $50 | |
| HDD | 4TB Seagate Constellation ES 7200 **NEW** | $47 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

**Approximate Price: $1,080 / $1,101**

### INTEL INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Corsair 4000D Airflow | $95 | |
| PSU | 550W XPG Pylon 80+ Bronze **NEW** | $60 | |
| Mobo | Gigabyte B660-M Gaming X AX **NEW** | $150 | |
| CPU | Intel Core i5-12600 **NEW** | $230 | |
| GPU | Gigabyte Eagle OC GeForce RTX 3060 8GB **NEW** | $329 | $460 |
| RAM | 16GB (2 x 8GB) G.Skill Ripjaws V CL16 @ 3600MHz **NEW** | $73 | |
| SSD | 500GB Team T-Force Cardea Graphene Z44L PCIe 4.0 M.2 SSD | $60 | |
| HDD | 4TB Seagate Constellation ES 7200 **NEW** | $47 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

**Approximate Price: $1,076 / $1,207**

## MID-RANGE

**WE WERE PLEASED** to see a solid discount on the Ryzen 7 5800X this month, a result of the new 5800X3D and associated chips launching. We looked at implementing one of these upgraded CPU variants to take advantage of the 3D processor's tripled L3 cache, but they are expensive for a small performance boost.

No such reduction for the i7-12700F processor, but also on sale is the EVGA SuperNOVA GA power supply in the Intel build, currently at $75. The NZXT PSU in the AMD system has gone above $100, though, so we swapped it out for the SuperNOVA G5.

While it might not have a cheaper CPU, the Intel build does see some small discounts; the DDR4 version of the Asus Prime Z690-P dropped to $170 this month, which is an excellent deal. Both machines also get a minor saving by swapping over to the Seagate Constellation ES we brought back for the budget builds.

The Intel build gets a new cooler, the Aquafusion 240 ARGB from Enermax, a dual-fan AIO cooler with slick addressable RGB lighting on the fan casings and pump block. It replaces a Corsair liquid cooler, which was no longer on sale, while the price of the Raijintek Orcus cooler in the AMD system held steady.

The midrange AMD build joins its budget sibling with an XFX Speedster GPU, the SWFT319 RX 6800 XT. A base discount plus a $40 promo code through Newegg.com made this the cheapest 6800 XT we've seen for ages, although midrange and high-end GPU pricing remains high. That said, the RTX 3070 is closer to its original RRP than ever, with a Gigabyte Eagle OC model here to match the one in the budget Intel machine.

There wasn't much else to change, as we're leaving both SSDs in place. The AMD steals the RAM of the Intel build though, since Corsair's Vengeance RGB RT is currently the best-value 32GB kit available at 3,600MHz with RGB lighting unless you want to brave lesser-known brands, such as v-Color or KLEVV.

### AMD INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Lian Li PC-O11-Dynamic | $154 | |
| PSU | 750W EVGA SuperNOVA 750 G5 80+ Gold **NEW** | $78 | |
| Mobo | Gigabyte X570 Gaming X | $120 | |
| CPU | AMD Ryzen 7 5800X | $318 | |
| Cooler | Raijintek Orcus 240 RBW ARGB | $80 | |
| GPU | XFX Speedster SWFT319 Radeon RX 6800 XT 16GB **NEW** | $649 | $770 |
| RAM | 32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz **NEW** | $152 | |
| SSD | 500GB Samsung 980 Pro NVME M.2 PCIe 4.0 SSD | $102 | |
| HDD | 4TB Seagate Constellation ES 7200 **NEW** | $47 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

**Approximate Price: $1,732 / $1,853**

### INTEL INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Lian Li PC-O11-Dynamic | $154 | |
| PSU | 750W EVGA SuperNOVA 750 GA 80+ Gold | $75 | |
| Mobo | ASUS Prime Z690-P LGA 1700 | $170 | |
| CPU | Intel Core i7-12700F | $313 | |
| Cooler | Enermax Aquafusion 240 ARGB 240mm **NEW** | $90 | |
| GPU | Gigabyte Eagle OC GeForce RTX 3070 8GB **NEW** | $499 | $600 |
| RAM | 32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz | $152 | |
| SSD | 500GB Corsair Force MP600 M.2 PCIe 4.0 | $81 | |
| HDD | 4TB Seagate Constellation ES 7200 **NEW** | $47 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

**Approximate Price: $1,613 / $1,714**

## TURBO

**WE'RE GOING FOR** a small but important upgrade to both our turbo systems this issue, with a step up from 80+ Gold efficiency rating on both power supplies to 80+ Platinum since the midrange systems are already rocking Gold PSUs. That means a new EVGA SuperNova P6 for the AMD build, while we're sticking with Corsair and upgrading to the HX850 in the Intel PC. Both are fully modular with an 850W power rating, which should only drop slightly below 90 percent efficiency at maximum load.

The Aorus Elite WiFi motherboard supporting our AMD system is still discounted, so we left it here. A sale of almost a third off the Asus Prime Z690-A DDR5 saw us swap out the other machine's mobo, though, keeping DDR5 support for our 12th-gen Intel processor for just $210; a steal for a DDR5 board right now.

A price drop in the processor department saw us shave more than $50 off the AMD turbo build and $10 from the Intel machine. SenyTech currently has an offer for a $40 Newegg.com gift card with any Ryzen 9 5950X purchase. And what's this we see in the AMD build? A high-end GPU for below RRP! Last month's ASRock's Phantom Gaming D edition of the RX 6900 XT is down to an incredible price of just $950. For the first time, we have a street price lower than our standard total price. No such reductions on the RTX 3090; last issue's EVGA FTW3 card is up $100, so we swapped over to our third Gigabyte GPU of the month in the Intel system to keep the price level.

The hefty cost of the RTX 3090 has been offset by a downward trend in the price of DDR5 memory, as the new RAM standard slowly penetrates the market. The 2x 32GB Corsair Vengeance kit we added last month is $50 cheaper, a more significant drop than the $10 we saved on the AMD build's memory. Lastly, the SSDs featured in last issue's turbo builds have gone up, so we got two new ones; the Gigabyte Aorus Gen4 7000s and XPG Gammix S70. Both should be capable of that crisp 7000MB/s sequential read speed that we've come to expect from PCIe 4.0 drives.

### AMD INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Phanteks Enthoo Pro 2 Tempered Glass | $190 | |
| PSU | 850W EVGA SuperNova P6 80+ Platinum **NEW** | $165 | |
| Mobo | Gigabyte X570 Aorus Elite WiFi | $190 | |
| CPU | AMD Ryzen 9 5950X | $598 | |
| Cooler | NZXT Kraken X72 360mm | $160 | |
| GPU | ASRock Radeon RX 6900 XT Phantom Gaming D 16GB | $999 | $950 |
| RAM | 64GB (2 x 32GB) G.Skill Trident Z Neo DDR4 @ 4000MHz CL18 | $330 | |
| SSD | 1TB Gigabyte Aorus Gen4 7000s M.2 PCIe 4.0 **NEW** | $150 | |
| HDD | 6TB WD Blue 5400 HDD | $70 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

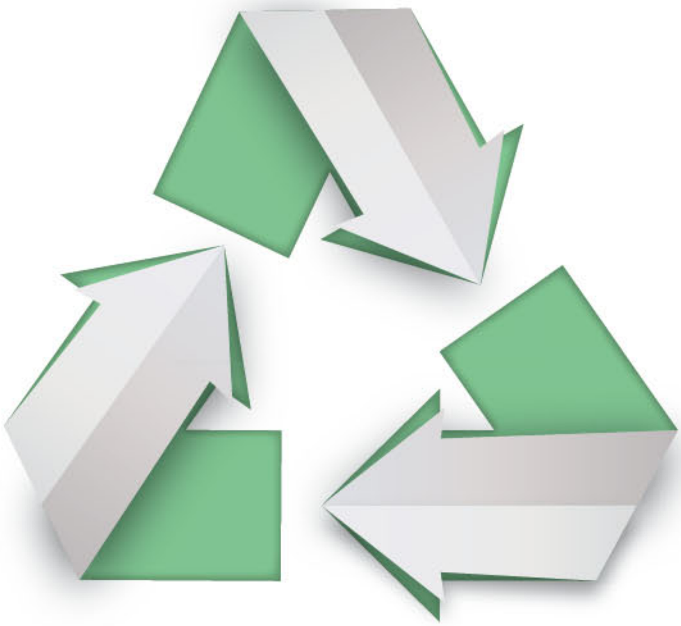
**Approximate Price: $2,884 / $2,835**

### INTEL INGREDIENTS

| PART | | PRICE | STREET PRICE |
|---|---|---|---|
| Case | Phanteks Enthoo Pro 2 Tempered Glass | $190 | |
| PSU | 850W Corsair HX850 80+ Platinum **NEW** | $151 | |
| Mobo | Asus Prime Z690-A LGA 1700 **NEW** | $210 | |
| CPU | Intel Core i9-12900K | $599 | |
| Cooler | MSI MAG CoreLiquid 360R V2 360mm | $124 | |
| GPU | Gigabyte GeForce RTX 3090 Gaming OC 24GB **NEW** | $1,500 | $1,700 |
| RAM | 64GB (2 x 32GB) Corsair Vengeance DDR5 @ 5200MHz | $490 | |
| SSD | 1TB Gammix Gaming S70 M.2 PCIe 4.0 SSD **NEW** | $130 | |
| HDD | 6TB WD Blue 5400 HDD | $70 | |
| OS | Windows 10 Home 64-bit OEM (Windows 11 Compatible) | $32 | |

**Approximate Price: $3,496 / $3,696**

*Maximum PC* (ISSN 1522-4279) is published 13 times a year, monthly plus a Holiday issue following the December issue, by Future US, Inc., 10th floor, 1100 13th Street, N.W Washington DC 20005, USA. Website: www.futureus.com. Periodicals postage paid at New York, NY, and at additional mailing offices. Newsstand distribution is handled by Curtis Circulation Company. Basic subscription rates: one year (13 issues) US: $30; Canada: US$30; Foreign: US$50. Canadian and foreign orders must be prepaid. Canadian price includes postage and GST (GST #R128220688). PMA #40612608. Subscriptions do not include newsstand specials. POSTMASTER: Send changes of address to *Maximum PC*, PO Box 2024, Langhorne, PA 19047, USA. Future US, Inc. also publishes *MacLife*, and *PC Gamer*. Entire contents copyright 2021, Future US, Inc. All rights reserved. Reproduction in whole or in part is prohibited. Future US, Inc. is not affiliated with the companies or products covered in *Maximum PC*. Reproduction on the Internet of the articles and pictures in this magazine is illegal without the prior written consent of *Maximum PC*. Products named in the pages of *Maximum PC* are trademarks of their respective companies. PRODUCED IN THE UNITED STATES OF AMERICA.



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